ESTIMATION OF SOCIO-ECONOMIC COSTS RESULTING FROM AIR POLLUTION IN THE INDOOR ENVIRONMENT

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ABSTRACT

Socio-economic costs in society due to indoor air pollution can help determine the type of these indoor pollutants, their sources, situations that need to be prioritized and buildings with a high risk of pollution, thus facilitating the appropriate development of public policies at national level. It is necessary to ensure the health and safety of the population through the use of advanced and environmentally friendly materials in constructions, even if they entail additional costs for the producer (investments for the development of ecotechnologies supported by ecodesign). The research carried out so far shows that the benefits obtained through the implementation of technologies and implicitly the obtained results (ecological materials) are superior if we compare them with the costs during the lifetime use of materials and the environmental impact.

Keywords: socio-economic cost; air pollution; indoor environment

REZUMAT

Costurile socio-economice existente la nivelul societăţii în urma poluării aerului din mediul interior ne pot ajuta să stabilim tipul acestor poluanți interiori, ai surselor acestora, situațiilor ce necesită prioritizare şi al clădirilor ce prezintă un grad ridicat de risc al poluării, facilitând astfel dezvoltarea corespunzătoare a politicilor publice la nivel naţional. Este necesară asigurarea sănătăţii şi securităţii populaţiei prin utilizarea materialelor avansate şi ecologice în construcţii chiar dacă acestea presupun costuri suplimentare pentru producător (investiţii pentru dezvoltarea de ecotehnologii susţinute de ecoproiectare). Cercetările realizate până în prezent ne arată faptul că beneficiile obţinute prin intermediul implementării tehnologiilor şi implicit a rezultatelor obţinute (materiale ecologice) sunt superioare dacă ne raportăm la costurile pe durata de utilizare a materialelor şi la impactul asupra mediului înconjurător.

Cuvinte cheie: costuri socio-economice; poluarea aerului; mediul interior

1. INTRODUCTION

Socio-economic costs in society due to indoor air pollution can help determine the type of these indoor pollutants, their sources, situations that need to be prioritized and buildings with a high risk of pollution, thus facilitating the appropriate development of public policies at national level.

From the point of view of research in the field, so far very few cost estimates of indoor air pollution have been made, the most possible cause being related to the impediments regarding the value assessment of the treatment of associated diseases (BOD - burden of disease) for a large category of indoor pollutants, as well as of the different exposure circumstances that may occur. At literature level, there is an analysis carried out in 2005 by the California Air Resources Board (CARB), by publishing an estimate of the initial costs incurred as a result of indoor air pollution, the types of pollutants that were considered in the analysis being the following: volatile organic compounds (VOC), carbon monoxide (CO), radon, the indoor environment affected by tobacco smoke (ETS) and mold. Based on the results of the study, it was concluded that indoor pollution has an economic cost of approximately $ 45 billion annually in the state of California, the major share of the cost being represented by tobacco exposure.

From a social point of view, in terms of disability-adjusted life-years (DALY), these being made up of all the years lost due to premature death or years of life with diseases associated with pollution. The assessment of disability-adjusted life years is based on a share of exposure to pollutants or a disease associated with the defined risk factor and national assessments of the target audience at risk of exposure or associated disease [1].

These days, people spend 87% of their time indoors (in a residential or commercial building) and another 6% in their cars, being continuously exposed to the indoor environment [2].

At the level of the Member States of the European Union, research in this field has found indoor pollution costs of 2 million DALY (Disability-Adjusted Life Years) per year, two thirds of which is allocated to particulate matter.

2. MATERIALS AND METHODS

According to existing research studies, a representative number of pollutants, including biological substances, as well as physical pollutants are found under different weights in indoor environments (Weschler, 2009; World Health Organization, 2010; Logue et al., 2011, 2012). Representative pollutants from the environment that require special analysis and implicit consideration in research studies are the following: chemicals that have the potential to be present in indoor environments, these being initially determined by the National Observatory of Indoor Air Quality (Kirchner, 2011); the existence of an international scientific agreement on health conditions associated with pollution that may occur over time; the possibility of creating accessible databases or scientific publications regarding the effects of indoor pollution on health; transparency of data for concentrations and types of indoor air pollutants at national level, leading to a more accurate assessment of the impact on health at a given point in time. A recent WHO report estimated that indoor smoke from solid fuels ranked as one of the top ten risk factors for the global burden of disease, accounting for 1.6 mil premature deaths each year [3].

From an economic point of view, indoor air pollution is a negative externality (e.g. an effect for which there is no originally scheduled monetary compensation for an exchange in which a party is harmed by intentional or unintentional behavior). In this respect, the socio-economic impact of indoor air pollution is decisive as the monetary value of the negative results of indoor air pollution (e.g. the size of resources consumed by society based on exposure to pollution).

Currently, two models of socio-economic costs of indoor air pollutants are known:

a) external costs, which determine the opportunity costs of the provided resources, these being obtained from the presence of indoor air pollution;
b) the effect on public finances obtained by polluting indoor air.

Thus, the level of total socio-economic costs and the associated health impact were estimated for each target pollutant using Equation (1), as follows:

$$W = \Delta CE + \Delta G \times (1 + \alpha) \tag{1}$$

with:

- W = socio-economic cost variation (€);
- ΔCE = external costs based on premature deaths, the loss of life quality (morbidity) and the production loss (€);
- ΔG = public financing costs (€);
- $(1 + \alpha)$ = a weighting factor demonstrating that a cost of 1 € in public finances corresponds to a $(1 + \alpha)$ € loss in public finances (according to Quinet et al. (2013), $\alpha = 0.2$).

In order to determine the level of costs of premature death and loss of quality of life, we must assign a certain economic value to human life. Thus, it is considered that the statistical value of life (LVS) is the economic opportunity to pay (WTP) in order to preserve the utility when the risk to which it is exposed varies over time (Δrisk), as described in Equation (2):

$$\mathrm{VSL} = \frac{\mathrm{WTP}}{\Delta \mathrm{risk}} \quad (2)$$

At the scale of the French state, the statistical value of life (VSL) is estimated at € 3,000,000 (Quinet, 2013). Equation (3) details the relationship between the value of one statistical year of life (VOLY) and the statistical value of life (VSL):

$$\mathrm{VSL} = \sum_{1}^{T} \frac{\mathrm{VOLY}}{(1+r)^t} \quad (3)$$

where:

- T = the number of remaining years of life expected, equal to 40 years, calculated based on the average age and the life expectancy, respectively equal to 40 and 80 years;
- r = the adjustment rate, equal to 2.5%;
- VOLY = the value of a statistical life year (equal to €115,000 - Quinet et al. 2013).

Moreover, the report by Lebègue et al. (2005) proposes to use an annual adjustment rate of 4% in the calculations, to take into account a possible increase in costs compared to the reference year. Thus, based on this analysis, the reference value adjusted for the number of years lost between the average age at death and life expectancy at birth, which was 80 years in 2004, will be used to determine the cost of a premature death resulting from pollution (Pison, 2005).

Also, the determined adjusted value will be multiplied by the number of premature deaths estimated to be associated with diseases with exposure to one of the pollutants analyzed in order to determine a total cost related to premature deaths (equation (4)). The total cost of mortality is given by the sum of the costs associated with each disease:

External cost of premature deaths =

$$n_d \times \sum_{i} \frac{\mathrm{VOLY}}{(1+r)^i} \quad (4)$$

with:

- n_d = number of premature deaths associated with a disease generated by one pollutant;
- VOLY= value of a statistical life year, €115,000;
- r = adjustment rate, 4%;
- i = number of life-years lost because of the disease.

Similarly, the costs associated with mortality will be estimated, the costs of quality of life being adjusted according to life expectancy with a certain associated disease. Thus, the adjusted costs will then be multiplied by the number of new cases for each disease associated with indoor pollution by exposing to one of the pollutants studied to finally obtain a total cost of loss of quality of life for a given disease (Equation (5)). The total cost of losing quality of life is the sum of the costs for each associated disease:

External cost of quality of life loss =

$$n_c \times \sum_{j} \frac{\delta \times \mathrm{VOLY}}{(1+r)^j} \quad (5)$$

with:

- n_c = number of new cases associated with a disease generated by one pollutant;
- δ = loss of quality of life, i.e., average disability weight defined by the WHO for the disease;
- VOLY = value of a statistical life year (€115,000);
- r = adjustment rate, 4%;
- j = number of years of life with a given disease prior to death.

Regarding the estimation of the costs related to public funding, they are represented in particular by the payments made for treatments and consist of expenses related to the medical care of patients, which are estimated using data from the National Cancer Institute.

Also, the expenditure related to research in the field of indoor air pollution was obtained using an approximate estimate of the number of equivalent whole rules associated with this topic at national level during 2004 (number = 108) and based on the average annual cost of a full rule, equivalent to € 99,000 which includes salary costs (including taxes) amounting to € 90,000 and associated expenses (10%).

The savings of public funds obtained by non-payment of the full or partial pension due to premature deaths were estimated. Thus, the amount of the average annual old-age pension in 2004 (€ 15,000) was adjusted by 4% in relation to the number of retirement years lost. Thus, the number of retirement years lost for each illness was estimated based on the average age of death, the retirement age of 60 years and a life expectancy of 80 years (equation (6)). The total cost for unpaid pensions is the sum of the costs for each illness:

Unpaid public pensions =

$$n_d \times \beta \times \sum_k \frac{P}{(1+r)^k} \qquad (6)$$

with:

n_d = number of premature deaths associated with a disease generated by one pollutant;

β = portion of retirement pensions from the public sector, 21%;

P = annual retirement pension value (€15,000);

r = adjustment rate, 4%;

k = number of retirement years lost because of the disease.

3. RESULTS AND DISCUSSIONS

The data used to determine the external cost of mortality for each disease are presented in Table 1 (number of deaths in 2004 and number of life years lost). For the calculation of the external cost of morbidity, the number of new cases for each disease in 2004 and the number of years to live with a particular disease generated by a pollutant are mentioned in Table 1. Also in Table 1 the number of retirement years lost for each illness is displayed, a value used to estimate the value of unpaid pensions.

Detailed of total socio-economic costs are shown in Table 2. As can be seen, the costs of indoor pollution in France have been estimated at around € 20 billion (2004):

Table 1. Estimate of the health impacts associated with exposure to each of the six target indoor air pollutants (France, 2004)

Pollutant	Associated health effect	Number of years with the disease	Average age at death	Number of years of life lost[a]	Number of years of pension lost[b]	Morbidity incidence	Number of deaths
Benzene	Leukemia	15	65	15	15	385	342
Trichloroethylene	Kidney cancer	1,5	65	15	15	41	15
Radon	Lung cancer	1,5	69	11	11	2388	2074
Carbon monoxide	Asphyxia	0	33	47	20	-	98
Particles	Lung cancer Cardiovascular diseases Chronic obstructive pulmonary disease (COPD)	1,5 13 12	69 77 79	11 3 1	11 3 1	2388 10.006 10.390	2074 10.006 4156
Environmental tobacco smoke (ETS)	Lung cancer Infarction Stroke COPD	1,5 13 11 12	69 77 80 79	11 3 0 1	11 3 0 1	175 1331 1180 150	152 510 392 60

[a] considering the life expectancy of the general population equal to 80 year old (Pison, 2005)
[b] considering the age of retirement equal to 60 year old.

Table 2. Costs of indoor air pollution exposure for the target pollutants (France, 2004) (Million €)

	Benzene	**Trichloro-ethylene**	**Radon**	**CO**	**Particles**	**ETS**	**Total**
External costs							
Premature death	-453	-19.6	-2089	-237	-5760	-322	-8880
Quality of life loss	-383	-6.7	-309	0	-7350	-837	-8886
Lost productivity	-38	-1.5	-282	-72	-1102	-85	-1580
Total external costs	-874	-27.8	-2680	-309	-14.212	-1244	-19.347
Public finances							
Health	-18	-2.9	-61	-3	-236	-37	-358
Research	*	*	*	*	*	*	-11
Unpaid pensions	10.7	0.45	49	4	136.5	88	289
Raw costs for public finances	-7.3	-2.45	-12	0.9	-99.5	-29	-80
Total costs for public finances	-8.8	-2.9	-14.4	1.1	-119.4	-35	-96
Total costs	-883	-30.7	-2694	-308	-14.331	-1182	-19.443

* overall evaluation for all the selected pollutants; CO: carbon monoxide; ETS: environmental tobacco smoke.

Following the analysis of the obtained results, it can be stated that the main factors leading to these cost levels are the associations of fixed costs regarding the loss of quality of life, production losses and premature deaths.

The share of all these external costs is about 99% of the total costs, with public finances having a cost share of about 1.0% of the total cost. It is also noted that depending on the type of pollutant and its associated health status, mortality costs are higher (eg. CO, trichlorethylene, radon), lower (e.g. ETS) or approximately equal (e.g. benzene, PM2.5) compared to morbidity costs. A pilot study in the United States showed that radon levels exceeded moderate risk levels in 18% household and high risk in 4% [4].

Economic costs of premature deaths from air pollution in the WHO European Region was 1431 billion US$ in 2010 [5].

It is necessary to ensure the health and safety of the population through the use of advanced and environmentally friendly materials in constructions with low volatile organic compound even if they entail additional costs for the producer (investments for the development of ecotechnologies supported by ecodesign) [6,7]. The concept of “ecodesign” and green products were introduced as strategies that companies could employ to reduce the environmental impacts associated with their production process [8].

4. CONCLUSIONS

The research carried out so far shows that the benefits obtained through the implementation of technologies and implicitly the results obtained (ecological materials) are superior if compared to the costs during the lifetime use of materials and the environmental impact.

In order to obtain very precise data on the assessment of the impact of indoor pollutants on health, it is necessary to know additional data on population exposures to this type of pollutants. An accurate assessment could be the basis for a cost-benefit analysis of reducing levels of exposure to indoor pollution, in order to identify the most effective approach. The data obtained could be used in the development of public health policies, thus confirming the need for further research into indoor air quality issues by researchers and public policy makers.

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