Mercredi 07 Février 2024

RENCONTRES INTERNATIONALES AIR & SANTÉ 2024

Biomasse : quels enjeux en terme d'amélioration des connaissances

Interventions magistrales

Intervention de :

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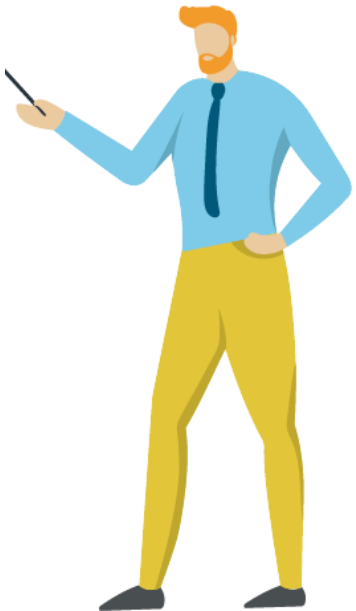

Session magistrale

Biomass: what's at stake in terms of improving knowledge?

Biomasse : quels enjeux en terme d'amélioration des connaissances

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Disclosures

International

- ERS Ethics and Integrity Committee (Member)
- EAACI ROC (WG PI)
- EAACI Environmental Guidelines
- AAAAI Environmental Exposures and Respiratory Health Committee
- WAO Environmental Committee
- ATS Health Policy Committee (previous member)

National

- IRD Ethics Committee (Previous President now member)
- Comité prévention et protection (CPP) MEDD
- SFA Scientific Committee (Member)
- CSTB Scientific Committee (Member)
- RNSA Scientific Committee (Member)
- Météo France (Commission Santé)
- Société de Pneumologie de Langue Française: GT PAPPEI
- Conseil d'Administration de l'APPA

- Section Editor for Environmental Health of ERJ and IJTLD

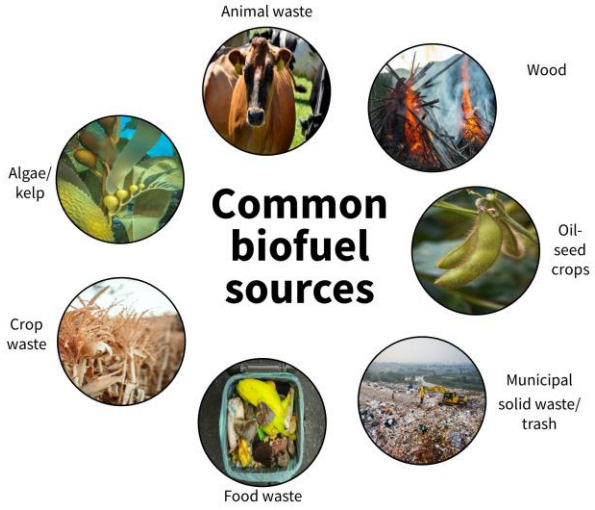
5 questions

1. What is biomass?
2. How much are individuals exposed to the various forms of biomass?
3. What are the health effects of biomass exposure?
4. What can be found to protect human beings from biomass health effects?
5. Biomass vs. climate change?

Introducing biomass and its burden

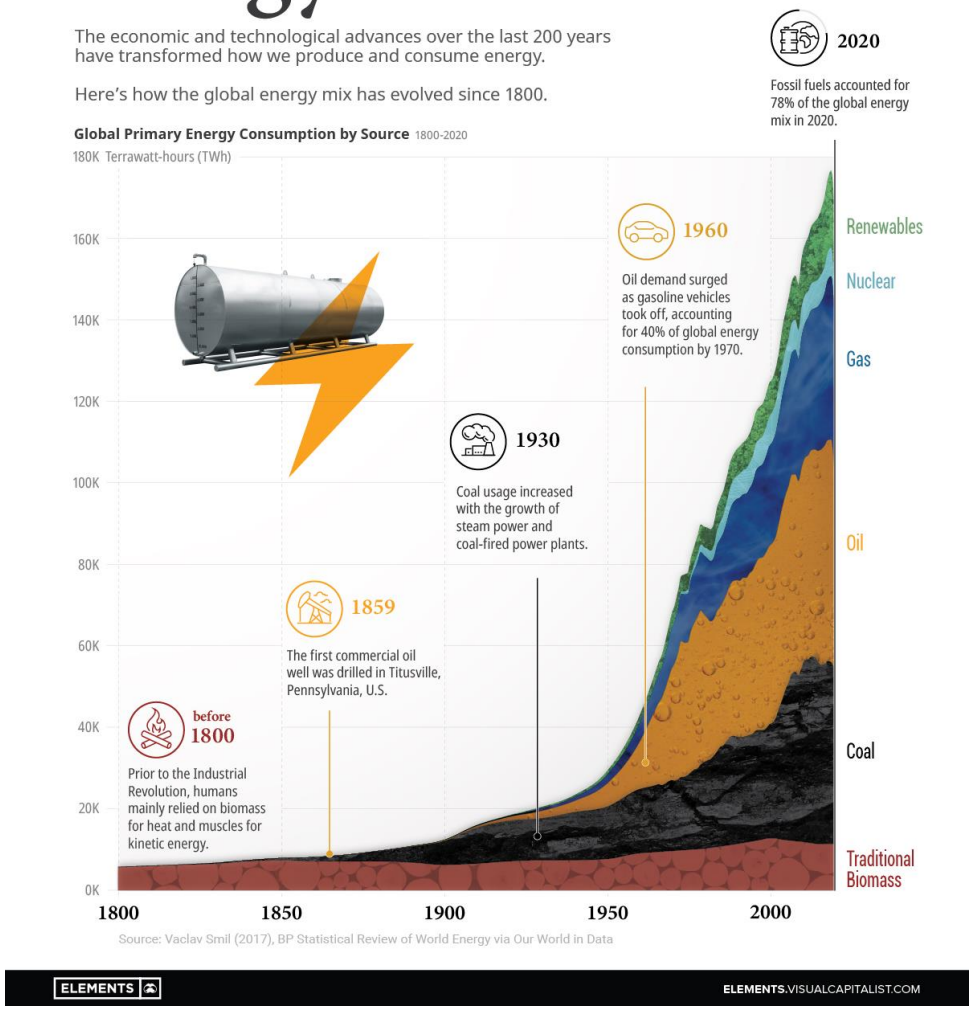
What is biomass?

Biomass is any living or recently living plant or animal-based material that is burned by humans as fuel, for ex. wood, dried animal dung, charcoal, grass and agricultural residue such as straw and sticks, dried leaves and twigs and wild grass.



Biomass the oldest kind of energy use

NOT ONLY ENERGY! The drawings in the Chauvet cave were made with pine charcoal.

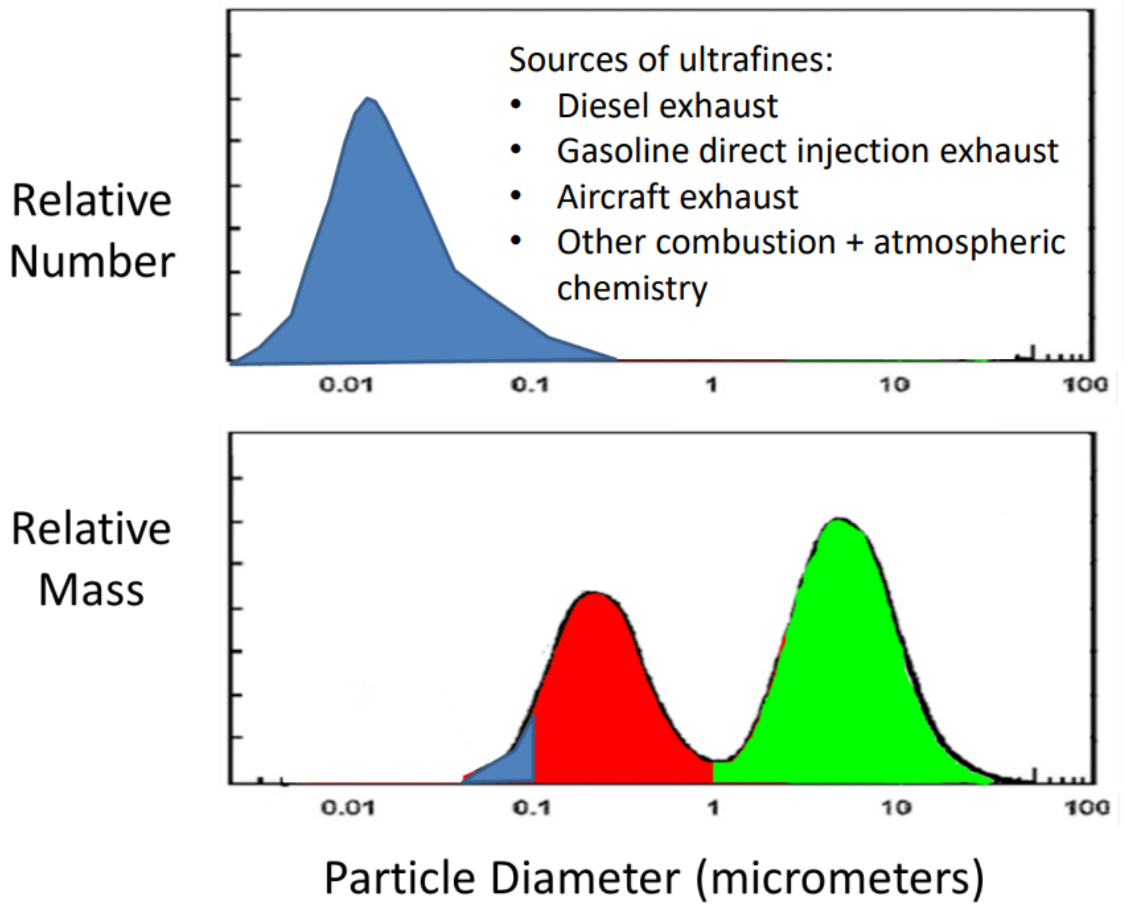


Biomass burning composition

200 compounds

- particulate matter (PM) of various size including UFP (Ultrafine Particles),
- carbon dioxide (CO_2),
- carbon monoxide (CO),
- nitrogen oxides (NOx),
- sulfur dioxide (SO_2),
- volatile organic compounds (VOCs)
- methane,
- non-methane hydrocarbons,
- nitric oxide (NO),
- methyl chloride,
- methyl bromine,
- lead, mercury, etc.
- PAHs (polycyclic aromatic hydrocarbons)

‘Ultrafine’ Particles



Adapted from Donaldson K et al. Occup Environ Med 2001;58:211-216

Particles – Does Size Matter? Or Mass? Or Number? Or What?

Mass Area ($\mu g/m^3$)	Diameter (μ)	Number (per ml)	Surface (μ^2/ml)
10	2	1.2	24
10	0.5	153	120
10	0.02	2,400,000	3016

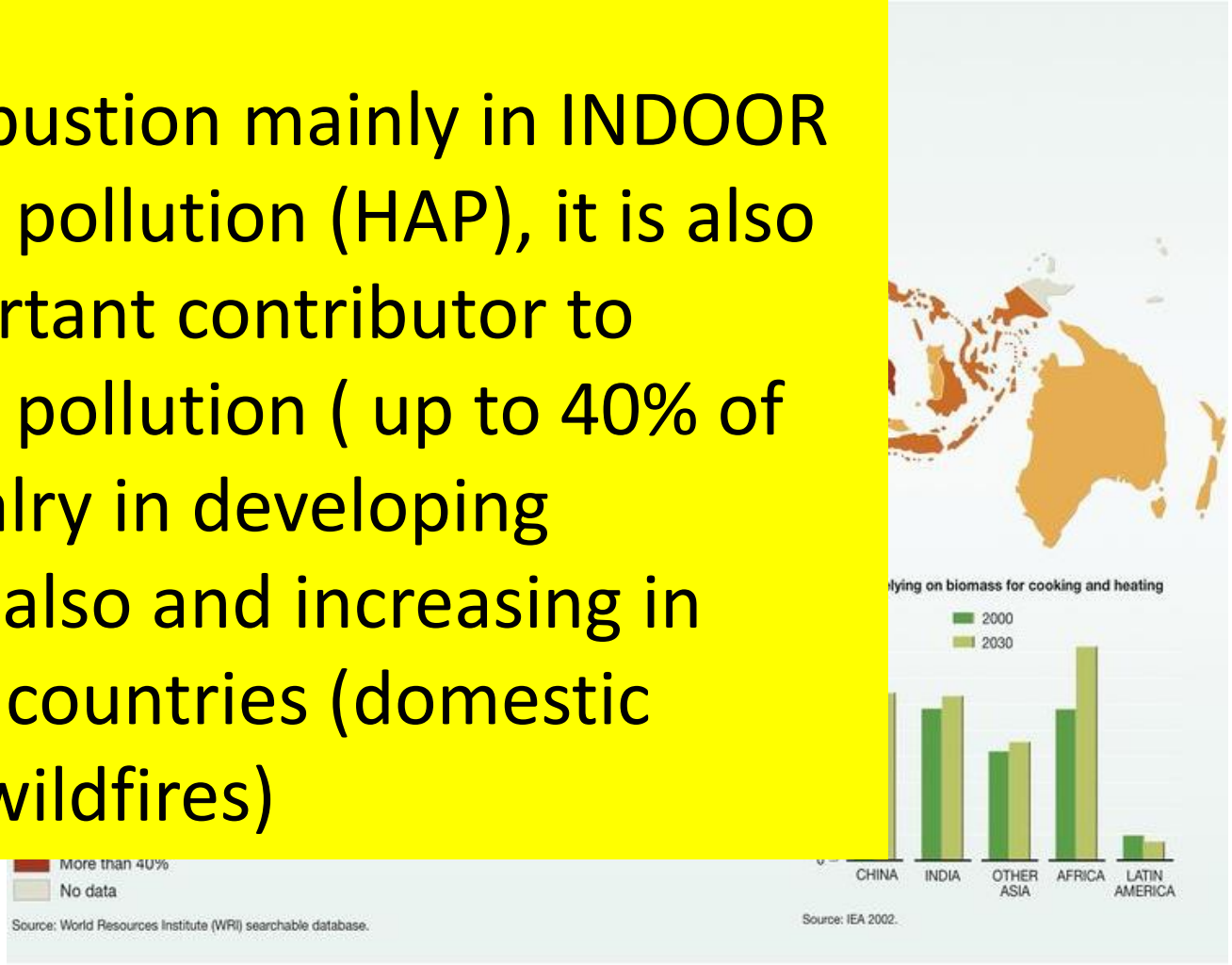
Adapted from Donaldson K et al. Occup Environ Med 2001;58:211-216

Biomass use/burden

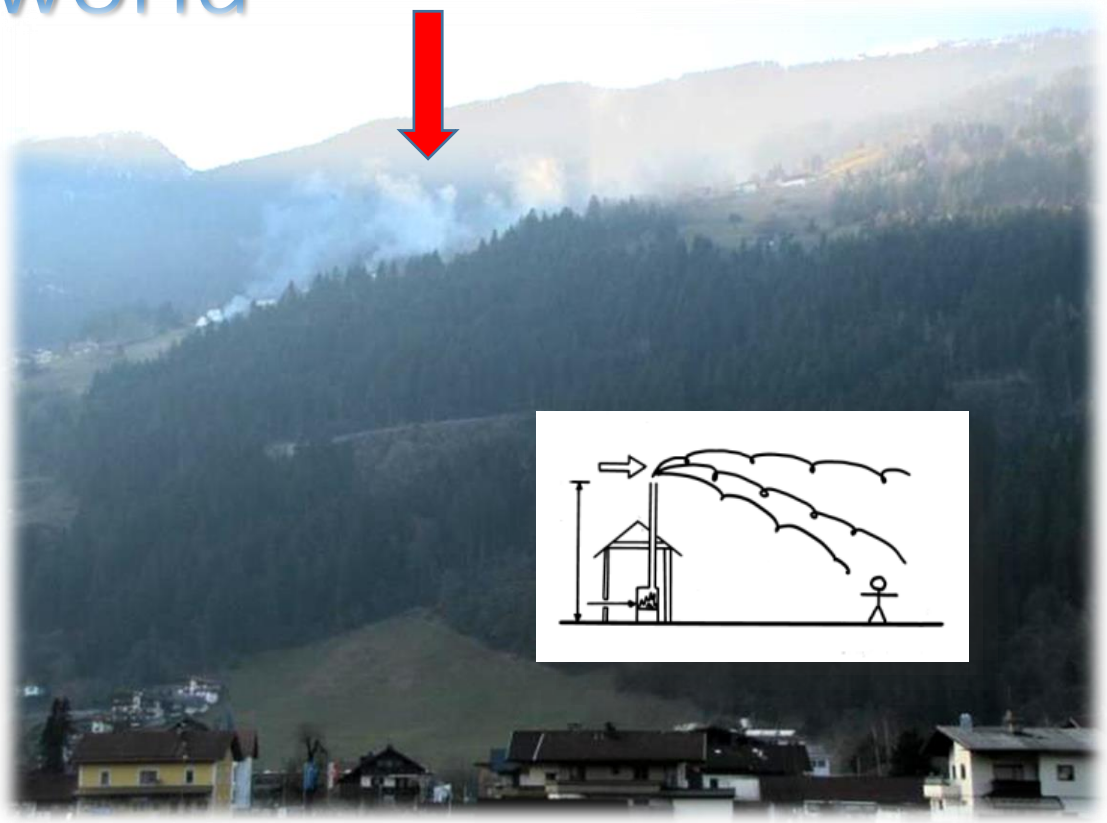
- Worldwide > 3 billio
  depend on biomass
  many natural source
  animals), which are
  burned for several p
  - developing countr
    lighting, and home
  - industrialized co
    heating
- Wildfires and planne
  land fires for agricul
- Occupational expos

Trends in use:

Biomass combustion mainly in INDOOR household air pollution (HAP), it is also but also important contributor to OUTDOOR air pollution (up to 40% of PM), particulalry in developing countries but also and increasing in industrialized countries (domestic heating and wildfires)



Biomass burning in the industrialized world



Across Europe, a shift towards renewable energy sources increases biomass incineration.

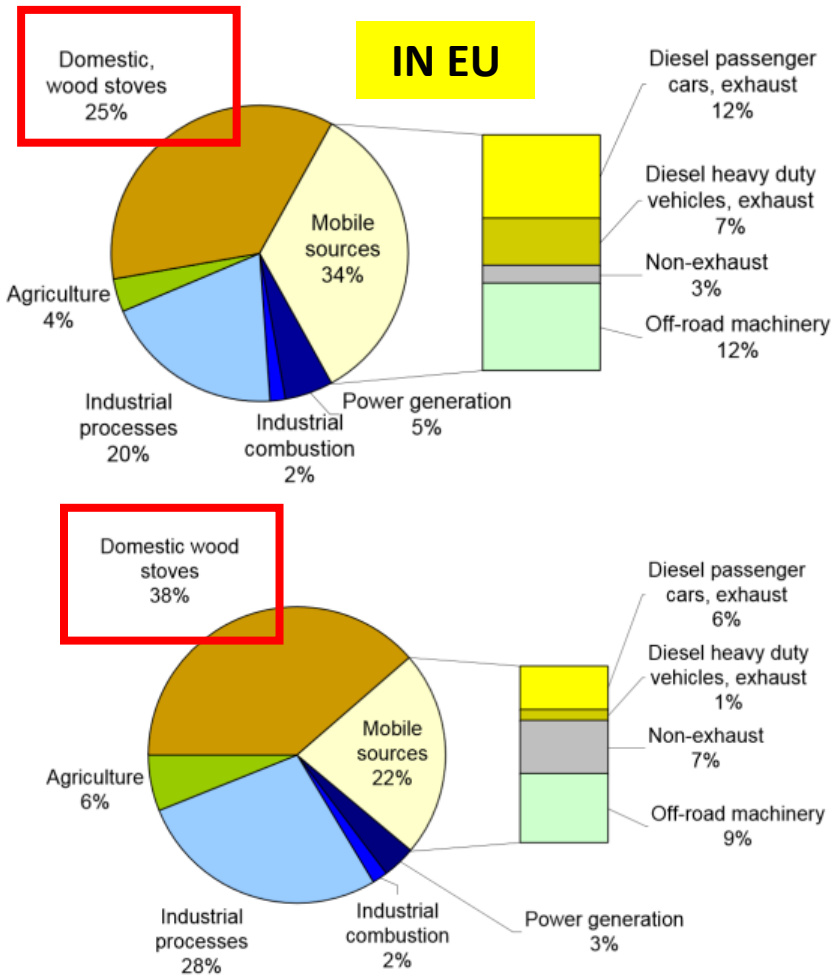
As a response to fuel poverty, biomass burning is seen as a cheap form of fuel & households are now the main source of fine particulate matter emissions in the EU.

Air pollution (IAP) induced by biomass use is very common and increasing

- Homes in developing countries : PM_{10}=300 - 5000 µg/m^3
- Homes in industrialised countries : PM_{10}=100-500 µg/m^3 in case of exclusive wood for heating

2000

2020

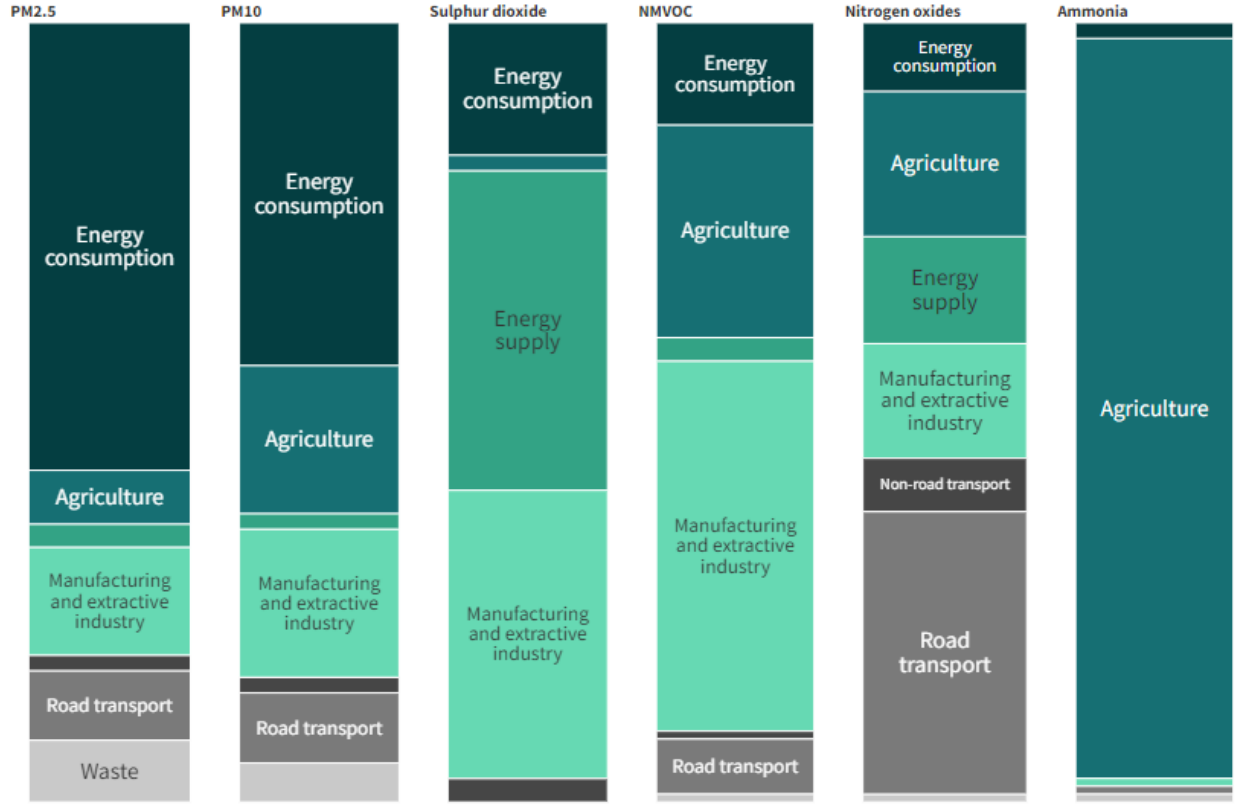


WHO Air Quality guidelines: annual 5 µg/m^3; daily 15 µg/m^3

Sigsgaard T, Forsberg B, Annesi-Maesano I. ERJ 2015

Biomass as an important sources of air pollution

- $PM_{2.5}$: residential, commercial and institutional energy consumption at 58%,
- PM_{10}: residential, commercial and institutional energy consumption at 44%,
- sulphur dioxide: energy supply at 41% and manufacturing and extractive industry at 37%,
- non-methane volatile organic compounds: manufacturing and extractive industry at 47%,
- nitrogen oxides: road transport at 37%,
- ammonia: agriculture at 94%



Source: European Environment Agency (EEA)
PM2.5 = fine particulate matter; PM10 = particulate matter; Energy consumption = residential, commercial and institutional energy consumption; NMVOC = non-methane volatile organic compounds.

nature

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Article | Published: 18 November 2020

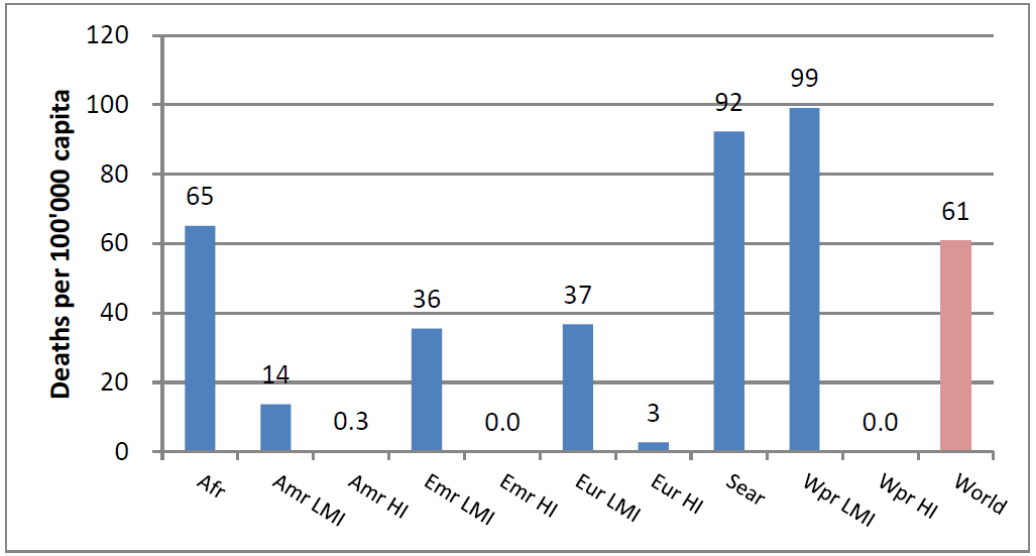
Sources of particulate-matter air pollution and its oxidative potential in Europe

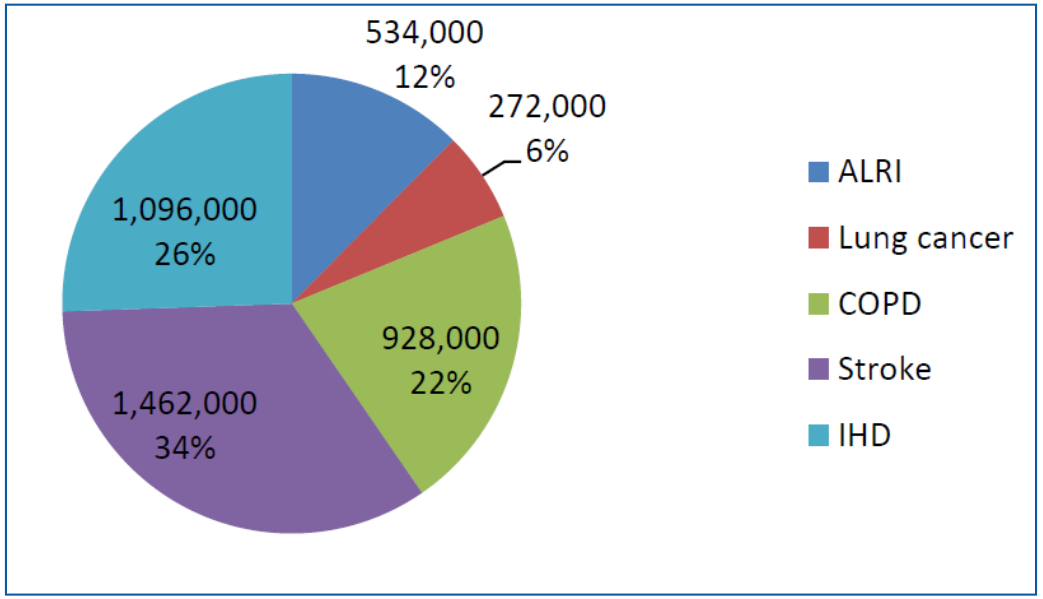
Kaspar R. Daellenbach, Gaëlle Uzu, Jianhui Jiang, Laure-Estelle Cassagnes, Zaira Leni, Athanasia Vlachou,

Abstract

Particulate matter is a component of ambient air pollution that has been linked to millions of annual premature deaths globally[1,2,3]. Assessments of the chronic and acute effects of particulate matter on human health tend to be based on mass concentration, with particle size and composition also thought to play a part[4]. Oxidative potential has been suggested to be one of the many possible drivers of the acute health effects of particulate matter, but the link remains uncertain[5,6,7,8]. Studies investigating the particulate-matter components that manifest an oxidative activity have yielded conflicting results[7]. In consequence, there is still much to be learned about the sources of particulate matter that may control the oxidative potential concentration[7]. Here we use field observations and air-quality modelling to quantify the major primary and secondary sources of particulate matter and of oxidative potential in Europe. We find that secondary inorganic components, crustal material and secondary biogenic organic aerosols control the mass concentration of particulate matter. By contrast, oxidative potential concentration is associated mostly with anthropogenic sources, in particular with fine-mode secondary organic aerosols largely from residential biomass burning and coarse-mode metals from vehicular non-exhaust emissions. Our results suggest that mitigation strategies aimed at reducing the mass concentrations of particulate matter alone may not reduce the oxidative potential concentration. If the oxidative potential can be linked to major health impacts, it may be more effective to control specific sources of particulate matter rather than overall particulate mass.

Burden of disease from biomass use





World Health Organization

Burden of disease from Household Air Pollution for 2012

Air pollution (IAP) induced by biomass use is one of the top 10 risks for the global burden of diseases (WHO

Globally, 4.3 million deaths (mostly in low / middle income countries) are attributable to household pollution (HAP), mainly due to solid (biomass) fuel combustion products.

In EU28: A recent WHO report estimated that ambient PM from residential heating with **wood and coal** is responsible for 61,000 premature deaths per year

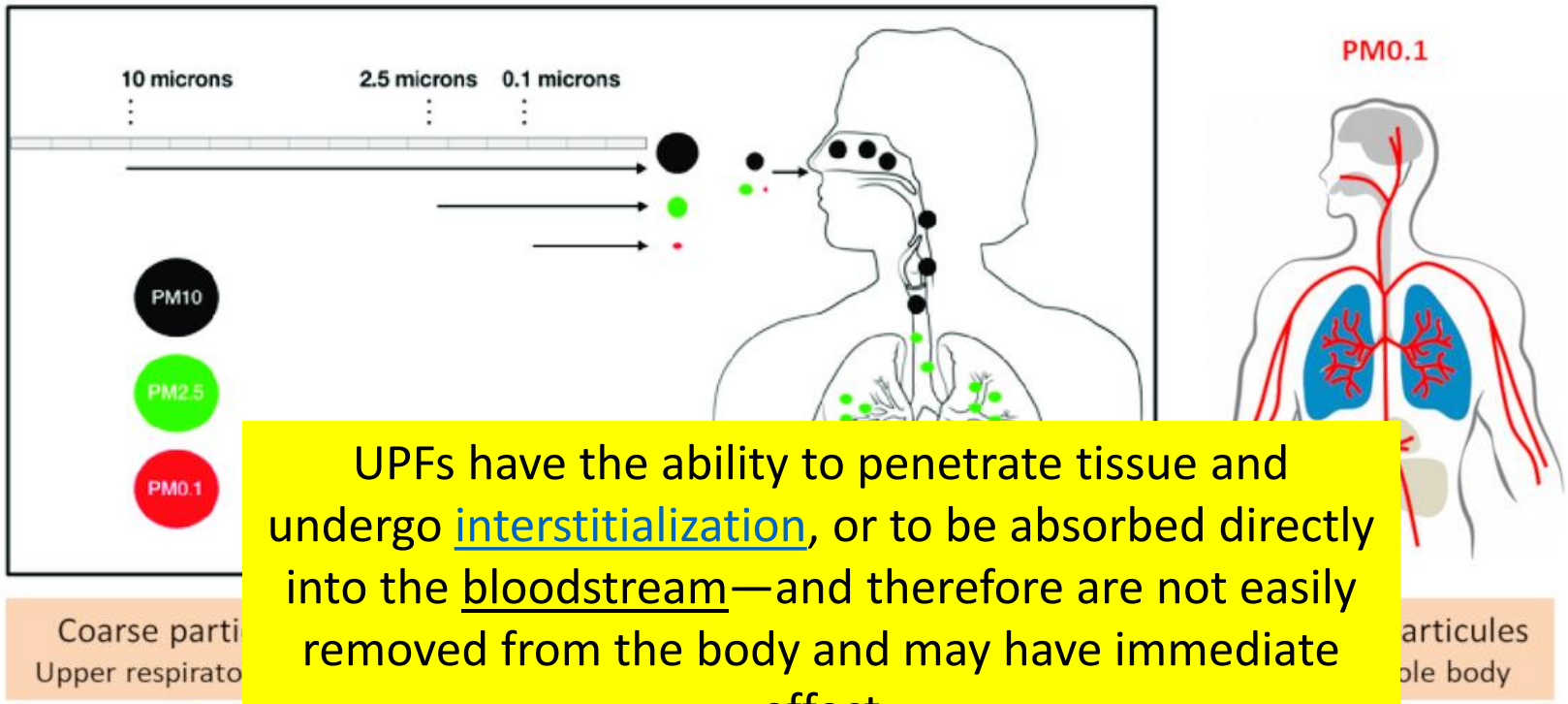
Amr: America, Afr: Africa; Emr: Mediterranean, Sear: South-East Asia, Wpr: Western Pacific; Eur: Europe; LMI: Low- and middle-income; HI: High-income.

ALRI: Acute lower respiratory disease; COPD: Chronic obstructive pulmonary disease; IHD: Ischaemic heart disease.

http://www.who.int/indoorair/health_impacts/burden/en/

Ultrafine Particles penetration

So tiny that it can pass through many of our body's protective armours such as mucous membranes and other barriers, to damage our lungs, heart, brain etc..



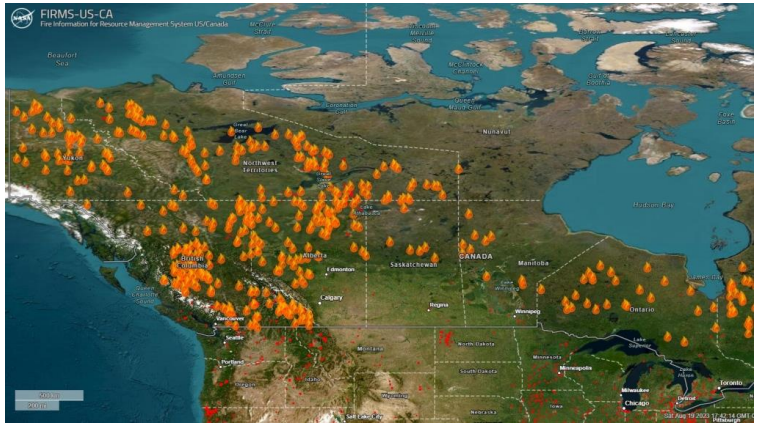
UPFs have the ability to penetrate tissue and undergo interstitialization, or to be absorbed directly into the bloodstream—and therefore are not easily removed from the body and may have immediate effect

What are the health effects of biomass?

- *Developing countries*
  - Acute respiratory infections in children (ARIs), respiratory symptoms (congestion, cough, phlegm) and diseases (asthma, COPD, TB, lung cancer, etc.), cardiovascular, cerebrovascular and metabolic diseases, reproductive and pregnancy health outcomes, cataracts in adults.
- *Industrialized countries*
  - Low birth weight, respiratory symptoms (congestion, wheeze) and bronchiolitis and asthma in young children, increased medication use, decreases in lung function, asthma and COPD emergency room visits and hospitalizations in adults.

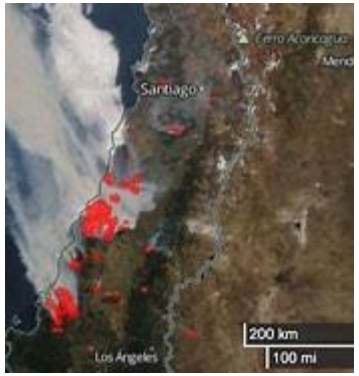
- *Wildfires*
  - Respiratory symptoms, asthma medication use, outpatient physician visits, emergency room visits, hospital admissions, and mortality
  - Firemen are highly exposed (but healthy worker effect)

Extreme air pollution events related to fires-related biomass: very high doses



Wildfires in Canada 2023 (NASA MAP)

Mega-fires in Canada: 14.2 million ha burned, 87,000 people affected, 1 billion tons of CO_2 released. **France=54,300,000 ha**



Wildfires in Chili 2024

Burning of rice straws in Thayland 2024

Respiratory infections

Household air pollution from biomass fuels accounts for nearly 41% of pneumonia deaths in children under 5 years old, totaling around 600,000 annual fatalities (WHO)

Home › Environmental Science and Pollution Research › Article

Indoor air pollution from solid fuel on children pneumonia in low- and middle-income countries: a systematic review and meta-analysis

Review Article | Published: 23 January 2022
Volume 29, pages 24574–24588, (2022) Cite this article

Environmental Science and Pollution Research

Aims and scope →

Submit manuscript →

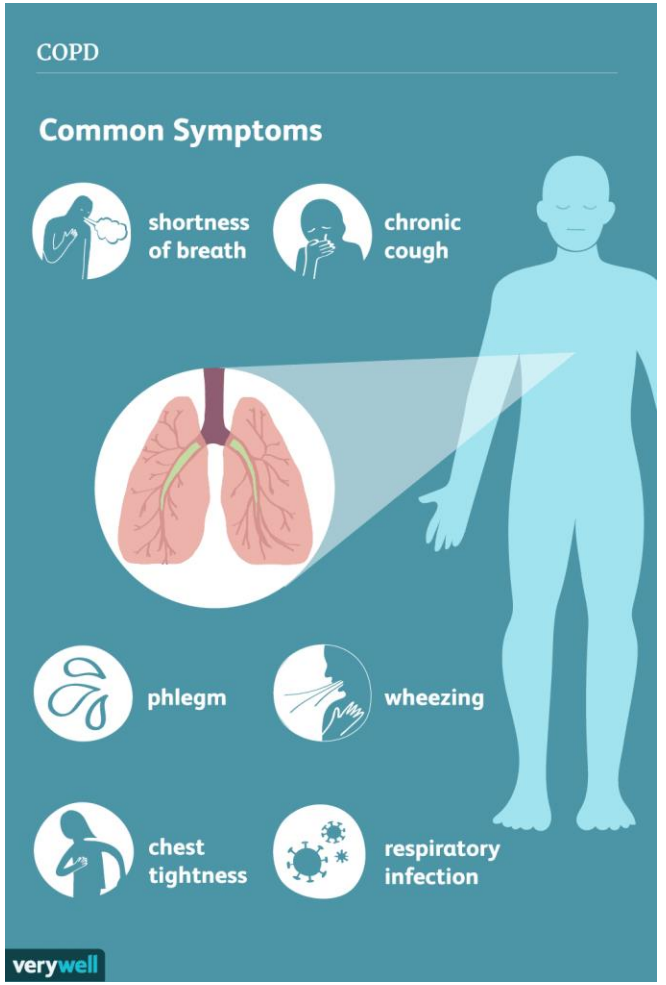
T. Chen et al.

1954 articles → 276 reviewed → 16 used in meta-analysis

Solid (biomass) fuel combustion significantly associated with an increasing risk of childhood pneumonia (OR = 1.66, 95%CI 1.36-2.02).

COPD

- COPD (Chronic Obstructive Pulmonary Disease) is the fourth leading cause of mortality globally, causing more than 3 million death annually and over 80% of these deaths occur in low- and middle-income countries.
- It is also a substantial cause of economic and social burden

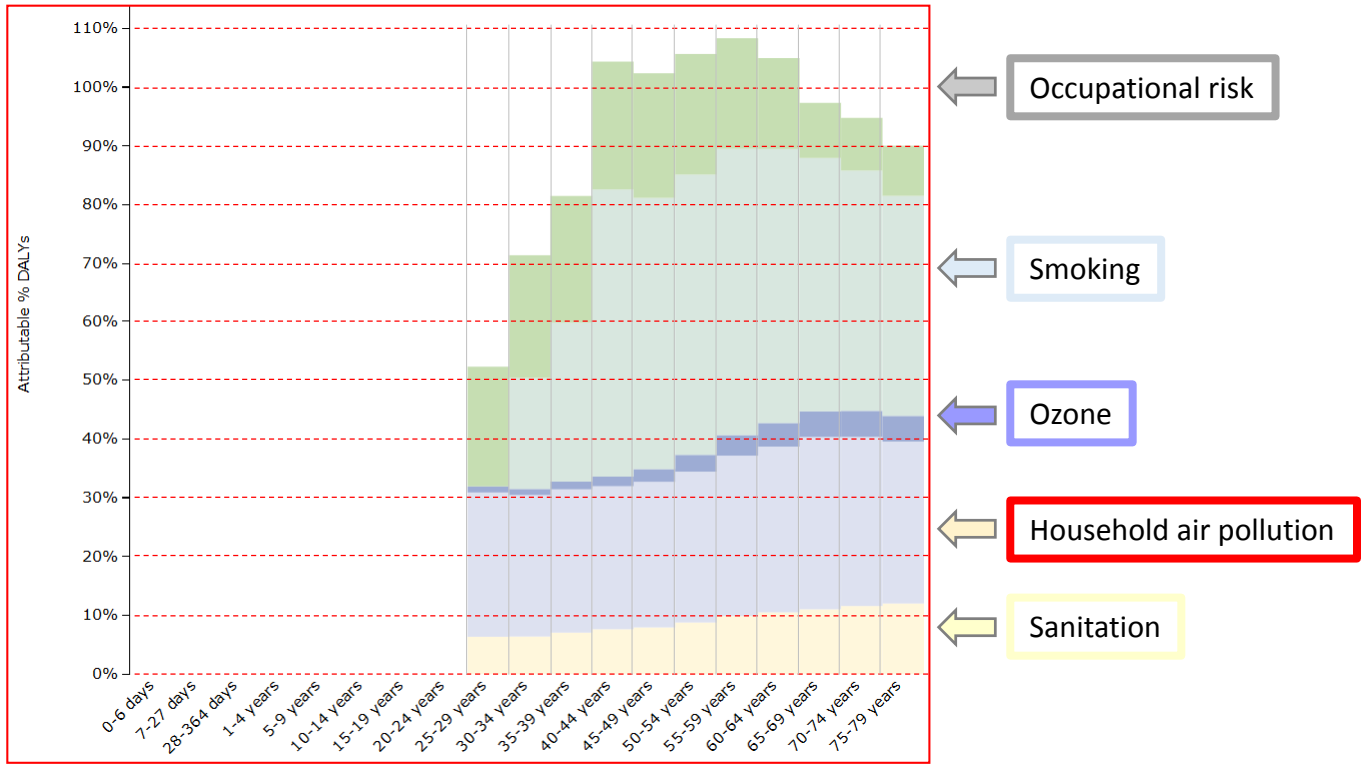


HAP is an important risk factor for COPD

IHME Institute for Health Metrics and Evaluation

Attributable DALYs for COPD

GBD Cause Patterns



COPD not only due to tobacco smoking!

http://vizhub.healthdata.org/gbd-cause-patterns/

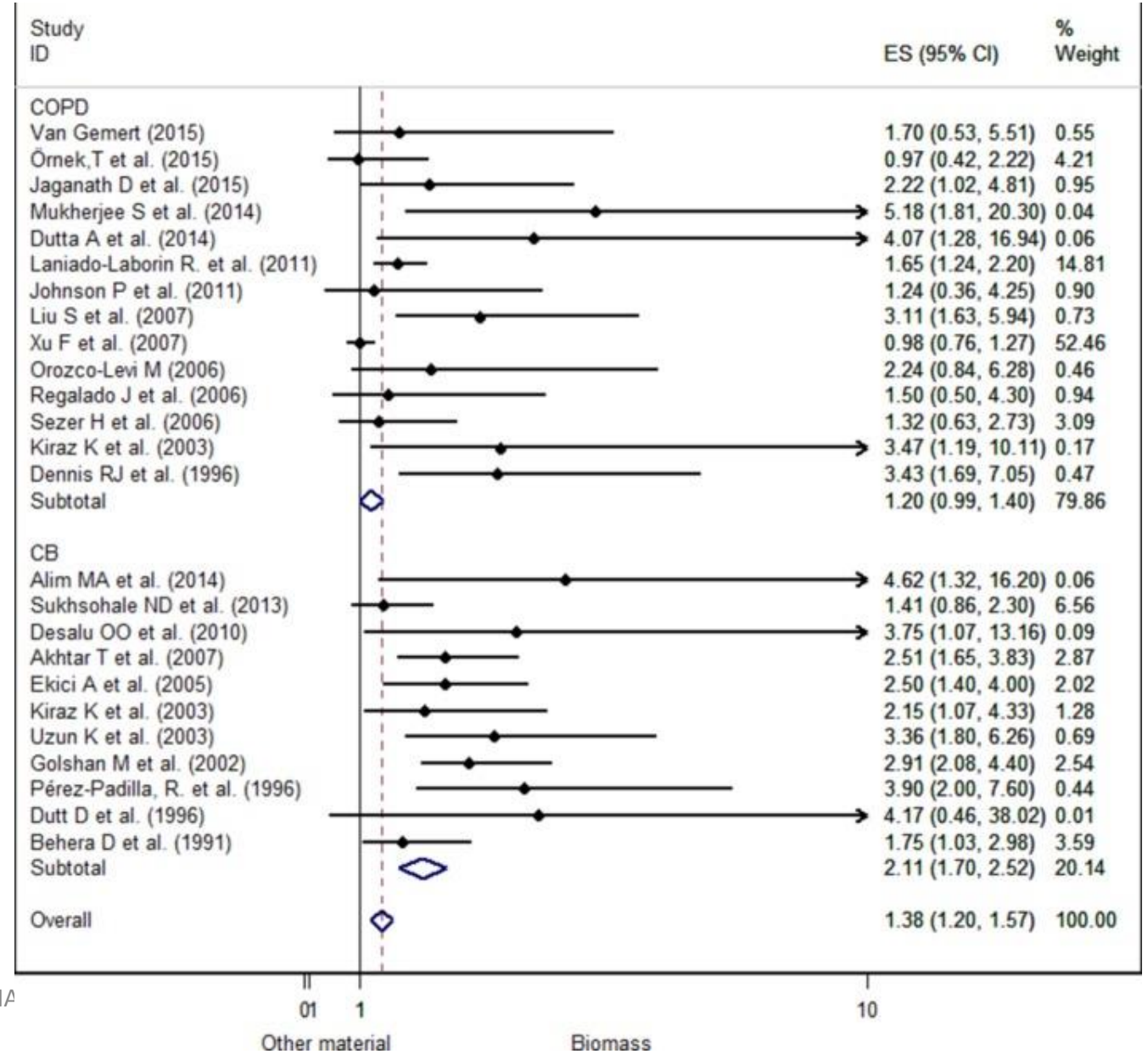
BMJ Open Respiratory Research

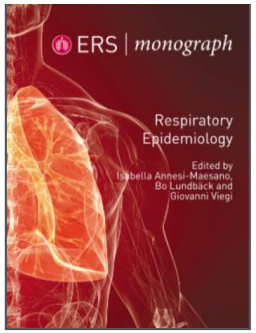
Chronic obstructive pulmonary disease associated with biomass fuel use in women: a systematic review and meta-analysis

2017

Adama Sana,[1,2,3] Serge M A Somda,[4,5] Nicolas Meda,[1,2] Catherine Bouland[3]

Biomass-exposed women were 1.38 times more likely to be diagnosed with COPD than non-exposed (OR 1.38, 95%CI 1.28 to 1.57)





chapter 13

Indoor pollution

2014

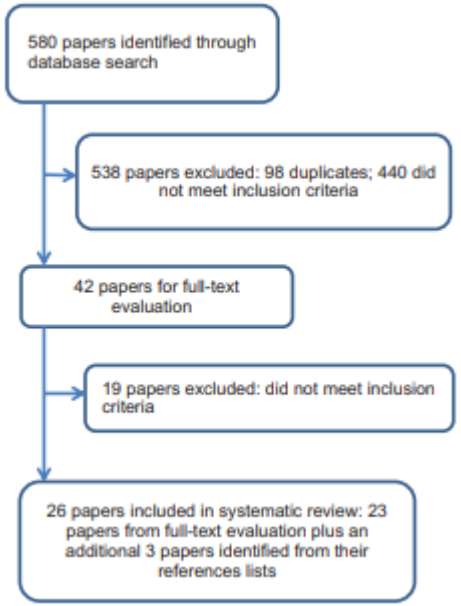
Marzia Simoni[1], Isabella Annesi-Maesano[2,3] and Giovanni Viegi[1,4]

Data from meta-analyses on the effects of exposures to the use of solid fuels / biomass.

Outcome	Smoke source	OR (95% CI)	RR (95% CI)
COPD	Solid fuels	2.8 (1.8–4.0)	
	Wood	4.3 (1.3–13.7)	
	Mixed biomass	2.3 (1.5–4.0)	
	Coal	1.8 (1.0–3.3)	
Females	Solid fuels		3.2 (2.3–4.8)
	Biomass fuels	2.4 (1.5–3.9)	
Males	Solid fuels		1.8 (1.0–3.2)
Chronic bronchitis	Solid fuels	2.3 (1.9–2.8)	
	Wood	2.6 (2.1–3.3)	
	Mixed biomass	2.5 (1.9–3.4)	
TB	Biomass fuels	1.5 (1.1–2.2)	
Acute LRTI#	Solid fuels		2.3 (1.9–2.7)
ARI#	Biomass fuels	3.5 (1.9–6.4)	

RR: relative risk; ARI: acute respiratory infection. #: in children.

Cardiovascular, cerebrovascular and metabolic diseases



MA of 26 studies, 10 in south Asia, 4 in China, 2 in Turkey, 1 in Iran and 8 in Central and south American:

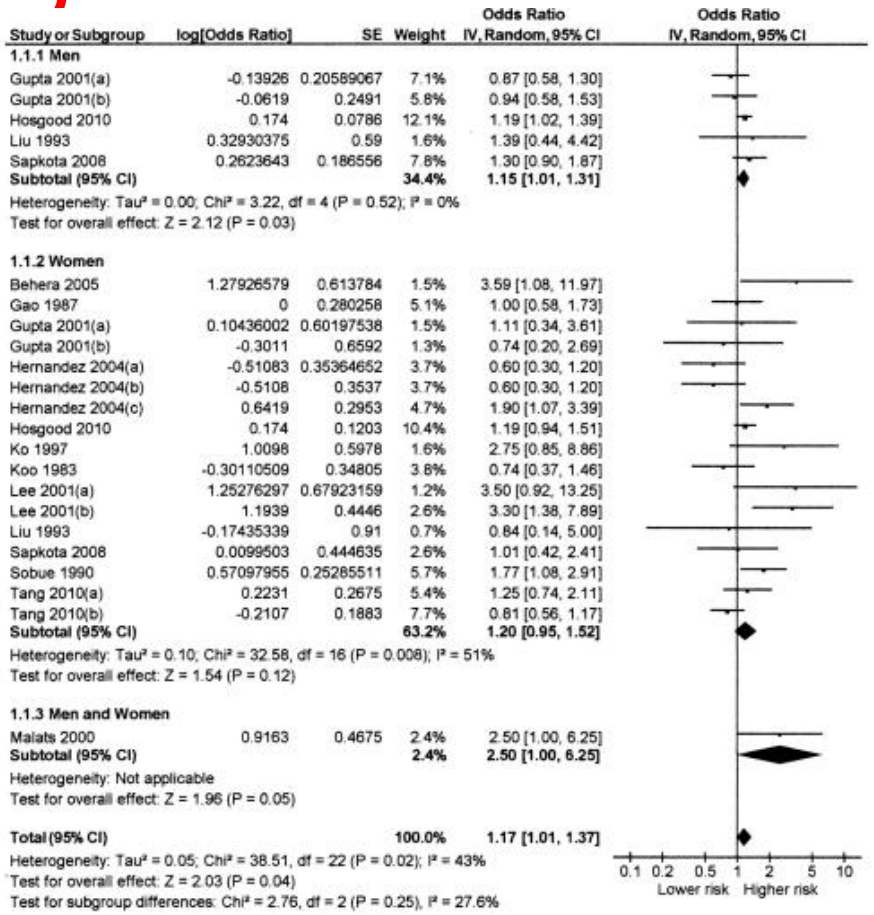
→ current balance of epidemiological evidence points to an increased risk of cardiovascular disease from HAP as a consequences of using solid and especially biomass for cooking and heating → Relative risks from long term exposure could be 2- to 4- fold

Fatmi, Coggon. BrMedBull 2016

Another study in 77,605 premenopausal women from 10 resource-poor countries → primary use of solid fuel associated with 0.58 mmHg higher systolic BP (95% CI: 0.23, 0.93) as compared to primary use of clean fuel **Arku Env Res 2018**

Lung, gastric/esophageal, cervical cancers

- Biomass emissions are a Group2A carcinogen (CIRC)
- Lung cancer causes more death globally than any other cancer and it is the seventh leading cause of death globally. About 1.5% of lung cancer death are attributed to exposure to carcinogens from biomass fuel smoke annually.



Study or Subgroup	log[Odds Ratio]	SE	Weight	Odds Ratio IV, Random, 95% CI
1.1.1 Men				
Gupta 2001(a)	-0.13926	0.20589067	7.1%	0.87 [0.58, 1.30]
Gupta 2001(b)	-0.0619	0.2491	5.8%	0.94 [0.58, 1.53]
Hosgood 2010	0.174	0.0786	12.1%	1.19 [1.02, 1.39]
Liu 1993	0.32930375	0.59	1.6%	1.39 [0.44, 4.42]
Sapkota 2008	0.2623643	0.186556	7.8%	1.30 [0.90, 1.87]
Subtotal (95% CI)			**34.4%**	**1.15 [1.01, 1.31]**
Heterogeneity: Tau² = 0.00; Chi² = 3.22, df = 4 (P = 0.52); I² = 0%				
Test for overall effect: Z = 2.12 (P = 0.03)				
1.1.2 Women				
Behera 2005	1.27926579	0.613784	1.5%	3.59 [1.08, 11.97]
Gao 1987	0	0.280258	5.1%	1.00 [0.58, 1.73]
Gupta 2001(a)	0.10436002	0.60197538	1.5%	1.11 [0.34, 3.61]
Gupta 2001(b)	-0.3011	0.6592	1.3%	0.74 [0.20, 2.69]
Hernandez 2004(a)	-0.51083	0.35364652	3.7%	0.60 [0.30, 1.20]
Hernandez 2004(b)	-0.5108	0.3537	3.7%	0.60 [0.30, 1.20]
Hernandez 2004(c)	0.6419	0.2953	4.7%	1.90 [1.07, 3.39]
Hosgood 2010	0.174	0.1203	10.4%	1.19 [0.94, 1.51]
Ko 1997	1.0098	0.5978	1.6%	2.75 [0.85, 8.86]
Koo 1983	-0.30110509	0.34805	3.8%	0.74 [0.37, 1.46]
Lee 2001(a)	1.25276297	0.67923159	1.2%	3.50 [0.92, 13.25]
Lee 2001(b)	1.1939	0.4446	2.6%	3.30 [1.38, 7.89]
Liu 1993	-0.17435339	0.91	0.7%	0.84 [0.14, 5.00]
Sapkota 2008	0.0099503	0.444635	2.6%	1.01 [0.42, 2.41]
Sobue 1990	0.57097955	0.25285511	5.7%	1.77 [1.08, 2.91]
Tang 2010(a)	0.2231	0.2675	5.4%	1.25 [0.74, 2.11]
Tang 2010(b)	-0.2107	0.1883	7.7%	0.81 [0.56, 1.17]
Subtotal (95% CI)			**63.2%**	**1.20 [0.95, 1.52]**
Heterogeneity: Tau² = 0.10; Chi² = 32.58, df = 16 (P = 0.008); I² = 51%				
Test for overall effect: Z = 1.54 (P = 0.12)				
1.1.3 Men and Women				
Malats 2000	0.9163	0.4675	2.4%	2.50 [1.00, 6.25]
Subtotal (95% CI)			**2.4%**	**2.50 [1.00, 6.25]**
Heterogeneity: Not applicable				
Test for overall effect: Z = 1.96 (P = 0.05)				
Total (95% CI)			**100.0%**	**1.17 [1.01, 1.37]**
Heterogeneity: Tau² = 0.05; Chi² = 38.51, df = 22 (P = 0.02); I² = 43%				
Test for overall effect: Z = 2.03 (P = 0.04)				
Test for subgroup differences: Chi² = 2.76, df = 2 (P = 0.25), I² = 27.6%				

Figure 2 Forest plot of 13 studies (23 estimates) reporting risk of lung cancer with use of biomass fuel in the household, stratified by sex
Notes on studies with more than one estimate (see table 2 for details):

Bruce Thorax 2015

Lung cancer

- First prospective study of wood burning and lung cancer incidence among 50226 U.S. women.
- Higher wood stove/fireplace usage associated with 70 % higher incidence of lung cancer.
- Associations were also elevated when analysis was restricted to never smokers.

Indoor wood burning raises women's lung cancer risk by 43%, says US study

Results from study involving 50,000 women suggest even occasional wood burning can contribute to lung cancer

Gas or propane heating in stoves and fireplaces was also associated with an increased lung cancer risk, but this was far smaller than that from wood burning. Photograph: Iolostock/Alamy

Using an indoor wood stove or fireplace increases women's risk of developing

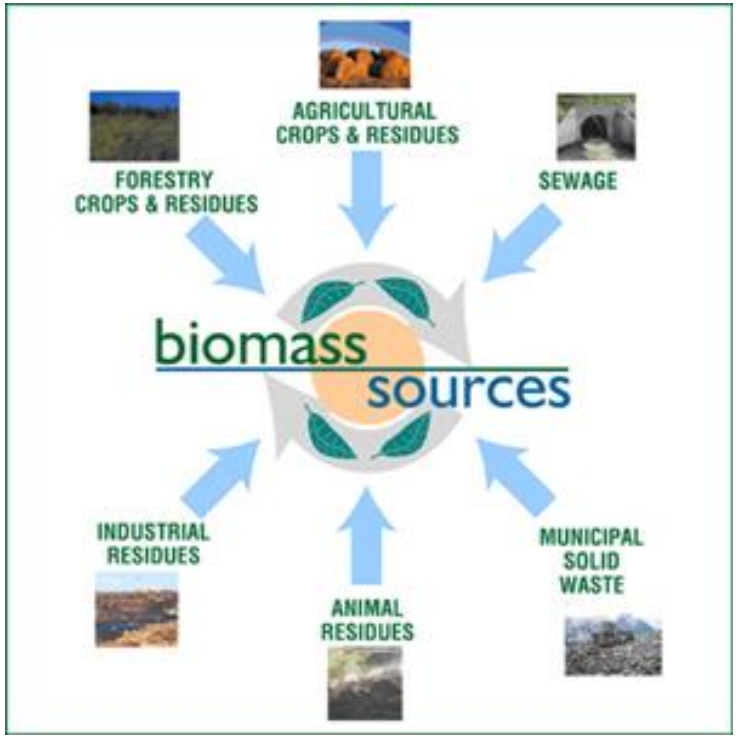
Mehta Env International 2023

Remediation, mitigation, adaptation

Improved cook stove, pellets, ventilation etc…

Primary prevention

Primary prevention covers all measures designed to avoid or reduce the risk of health problems (illness, accident, disability). It takes into account not only individual risk behaviors, but also environmental and societal issues.



While cigarette smoking is the leading preventable cause of COPD in the developed world, indoor solid fuel smoke exposure may be the leading preventable cause in lesser developed countries, particularly among women.

Trials of intervention to reduce biomass exposure

- **Childhood ALRIs**

No significant benefit with improved cook stove in MA (**Saleh IJTLD 2020**)

- **COPD**

Significant reduction in COPD: significant reduction in COPD among women with improved cook stove: RR = 0.74 (95% CI 0.61 to 0.90) in MA (**Thakur Thorax 2018**)

- **Asthma** (sparse data):

No improve of childhood asthma quality of life in a randomized control trial of air-filter intervention (**Noonan EHP 2018**)

- **Low birth weight**

An increase of 89 g in the birth weight of children of mothers using the intervention stoves (vs. open fires) (95% CI −27, 204), and reduced odds of a low birth weight child (OR 0.74, 95% CI 0.33–1.66) (**Thompson EHP 2011**)

Emissions of pelletized biomass fuel: UFP and BC

- In 2018, global wood pellet consumption increased by 130% compared to its 2013 levels, reaching 53 million tons.
  - Half of this consumption took place in Europe (27 million tons; a 60% increase in 5 years), where pellet consumption, for heating purposes only, increased by 220% during the 2013–2018 period, accounting for 15.8 million tons in 2018.-
- In 2019, European pellet consumption increased by 7%, an increase of 1.8 million tons in just one year.

→ The fresh pellet stove PM_1 emissions consisted mainly of Organic Aerosol and black carbon (BC), carbon dioxide and monoxide, nitrogen oxides, and a wide range of volatile organic compounds (VOCs)

Flourou Env Sci Atmos 2023

Emission factor (EF) of metals from pelletized and uncompressed biomass fuels

Table 1 | EFs (mg/kg, dry basis) of Pb, Cu, Cd, Ni and As for combustion of biomass pellets and raw biomass flues. The results include gaseous phase (G), particle-bound phase (P), and total emission (T). Data are presented as mean ± standard deviation (the sample size is three for each type of fuel)

Biomass		Pb	Cu	Cd	As	Ni
Corn straw	P	0.94 ± 0.28	0.70 ± 0.54	0.09 ± 0.01	8.39 ± 1.57	0.26 ± 0.01
	G	0.05 ± 0.03	0.95 ± 0.50	ND	ND	0.14 ± 0.01
	T	0.99 ± 0.24	1.65 ± 1.04	0.09 ± 0.01	8.39 ± 1.57	0.41 ± 0.003
Corn straw pellet	P	4.07 ± 0.59	2.28 ± 0.55	0.15 ± 0.05	15.81 ± 4.44	0.55 ± 0.21
	G	0.62 ± 0.07	4.11 ± 1.13	ND	ND	0.65 ± 0.14
	T	4.69 ± 0.52	6.39 ± 1.69	0.15 ± 0.05	15.81 ± 4.44	1.20 ± 0.07
Pine wood chip	P	0.85 ± 0.38	2.77 ± 0.90	0.12 ± 0.02	13.11 ± 0.15	0.22 ± 0.05
	G	0.19 ± 0.04	1.41 ± 1.32	ND	ND	0.23 ± 0.19
	T	1.04 ± 0.43	4.18 ± 0.42	0.12 ± 0.02	13.11 ± 0.15	0.45 ± 0.24
Pine wood pellet	P	3.71 ± 1.53	1.96 ± 0.20	0.17 ± 0.09	37.10 ± 2.69	0.70 ± 0.43
	G	0.67 ± 0.14	5.12 ± 0.17	ND	ND	0.25 ± 0.08
	T	4.39 ± 1.68	7.08 ± 0.38	0.17 ± 0.09	37.10 ± 2.69	0.95 ± 0.51

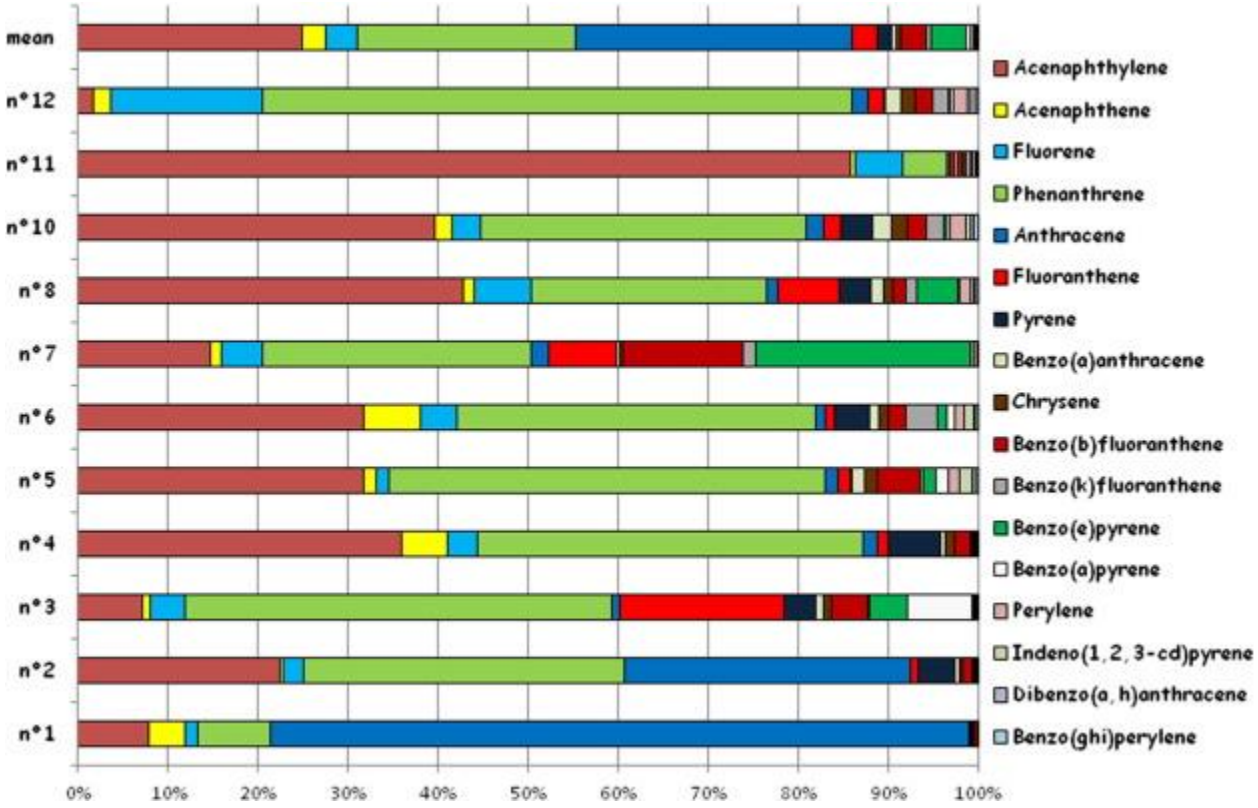
ND: not detected.

Zhang Scientific Reports 2014

Emission factor (EF) of Polyciclic aromatic hydrocarbons (PAHs) from pelletized biomass fuels

Ashes from 11 different pellet types fired in domestic stoves characterized by the presence of 17 PAHs produced by secondary aromatization reactions in the pyrolytic phase of incomplete combustion at temperatures higher than 400 °C.

→ threat to the people and environment due to the presence of carcinogen and mutagen PAHs



Orecchio Licrochemical Journal 2015

The relationship between biomass combustion and climate change is complex and depends on a variety of factors.

Potential benefits:

- Renewable resource: Biomass, like wood or biofuels, can be a renewable energy source if managed sustainably. Unlike fossil fuels, it can be replanted or regrown.
- Carbon neutrality: In theory, burning biomass releases the same amount of carbon dioxide that the plant absorbed during its growth, creating a closed carbon cycle. This could potentially offset fossil fuel emissions, leading to reduced greenhouse gas levels in the atmosphere.

Potential drawbacks:

- Incomplete combustion: Burning biomass can release particulate matter, nitrogen oxides, PAHs and other pollutants that contribute to air pollution and health problems.
- Deforestation: Unsustainable harvesting of wood for biomass can lead to deforestation, which releases large amounts of carbon stored in trees and reduces future sequestration potential.
- Soil degradation: Intensive biofuel crop production can deplete soil nutrients and contribute to soil erosion, negatively impacting land fertility and carbon storage.
- Limited carbon neutrality: Achieving true carbon neutrality with biomass is challenging due to factors like transportation, processing emissions, and potential land-use changes.

Flourou Env Sci Atmos 2023

Take home messages

- **Biomass use is very common and increasing also in industrialized countries. Biomass burning pollutes both indoors and outdoors**
- **Population studies** have shown that exposure to biomass particles is associated with severe morbidity and mortality (not only respiratory).
  Methodological issues
  - Confirmed by experimental studies
- **Intervention studies** have shown beneficial effects of phasing out biomass for heating (a beneficial effect was also seen after introduction of air filtering devices in the homes of the elderly (data not shown) for COPD and Birthweight)
- Efficient conversion technologies minimizing emissions have not shown their benefits

Other data needed

- **Pellet combustion** may pose threat to the people and environment due to the presence of UFPs, BC, carcinogen and mutagen PAHs
- Careful consideration of the entire lifecycle of biomass – from cultivation and harvesting to conversion and combustion – is crucial to assess the true environmental impact involved in climate change.

Perspectives

- Important regulatory steps would be:
  - the unconditional adoption of the outdoor 2021 PM_{10} and $PM_{2.5}$ WHO Air Quality Guideline values to protect public health.
  - the implementation of UFP WHO Air Quality Guideline values
  - The implementation of indoor Air Quality Guidelines