Particulate matter from tobacco *versus* diesel car exhaust: an educational perspective.

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Abstract. Background. Air pollution is a common alibi used by adolescents taking up smoking and by smokers uncertain about quitting. However, environmental tobacco smoke(ETS) causes fine particulate matter (PM) indoor pollution exceeding outdoor limits, while new engines and fuels have reduced particulate emissions by cars. We present data comparing PM emission from ETS and a recently released diesel car. **Methods.** A 60 m^3 garage was chosen to assess PM emission from 3 smoldering cigarettes (lit sequentially for 30min) and from a TDCi 2000cc, idling for 30min. **Results.** Particulate was measured with a portable analyser with readings every 2 minutes. Background PM_{10}, $PM_{2.5}$ and PM_1 levels [ug/m^3, mean (SD)] were 15 (1), 13 (.7) and 7 (.6) in the car experiment and 36 (2), 28 (1), and 14 (.8) in ETS experiment, respectively. Mean (SD) PM (ug/m^3) recorded in the first hour after starting engine were 44 (9), 31 (5), and 13 (1), while mean PM in the first hour after lighting cigarettes were 343 (192), 319 (178), 168 (92) for PM_{10}, $PM_{2.5}$ and PM_1, respectively ($P<0.001$, background corrected). **Conclusions.** ETS is a big source of PM pollution, contributing to indoor PM concentrations up to ten-fold those from an idling ecodiesel engine. Besides to its educational usefulness, this knowledge should also be considered in an ecological perspective.

Introduction.

Air pollution due to particulate matter (PM) is a risk factor for chronic obstructive pulmonary disease and asthma, and for lung cancer [1-3]. In addition, it has been shown that each increase of 10µg/m^3 in ambient PM levels carries on a short-term health burden that can be calculated in terms of morbidity and mortality [4], and is perceived as a serious threat by lay persons and decision makers. Accordingly, official annual average PM limits have been set at 40 µg/m^3 for PM_{10} in Europe, and at 15 µg/m^3 for $PM_{2.5}$ in the United States.

Environmental tobacco smoke (ETS) presents health risks similar to those of air pollution as for respiratory and cardiovascular diseases [1-3,5], and is being counteracted by regulations in most countries [6]. Nonetheless even health personnel are often unaware of such risks, and paradoxically, the presence of air pollution is commonly utilised as an alibi by smokers in an attempt to minimise the health risk linked to tobacco smoking [7].

The composition of ETS is similar to other fossil fuel combustion products that contribute to air pollution, and has been shown to be responsible for indoor PM levels far exceeding official outdoor limits [8,9]. This knowledge can be used to elaborate an educational message on smoking prevention based on indoor *versus* outdoor pollution, an issue of concern also for tobacco industry, as disclosed by the attempts to produce cigarettes with low PM emissions [10].

An additional message could derive from the comparison between PM production by cigarettes and by the new low-emission cars. It has been estimated that older gasoline vehicles and light-duty diesel emission rates are on average100 times higher than those for newer vehicles, and that 1991–1996 cars and trucks currently account for only 3.8% of PM pollution as compared to 26.8% due to 1986–1990 cars [11]. In addition, low-sulphur fuel for diesel engines reduces secondary PM formation [12]. To explore the issue, we carried out an experimental study to compare PM production from ecodiesel exhaust and smoldering cigarettes.

Methods. The experiments were carried out in Chiavenna, a small mountain town in northern Italy, chosen because of usually low outdoor PM levels. A private garage of 60 m^3 with a balancing door endowed with six small vents of 25 cm 2 each (kept always opened as required by law to ensure continuous air exchange), was the setting for a series of measurements. Recordings of 40 minutes were done with the door open before each experiment to measure background PM levels, then the door was kept closed until the end of the experiment. Between each experiment the door was kept open for at least four hours to obtain adequate air exchange.

In the first kind of experiments a diesel engine was started and left idling (760 rpm) for 30 minutes. In the second kind of experiments, three cigarettes were sequentially lit up and left smoldering, for an overall of 30 minutes. Recordings were continued for additional 90 minutes. The car was a turbo diesel common rail 2.0 liters Ford Mondeo, year 2002, that complied with the Euro3 gas exhaust standards. The engine was fuelled with low-sulphur "bludiesel" fuel produced by AGIP (a consociate of ENI, the Italian Hydrocarbons Agency), containing only 10 parts per million of sulphur (10mg/kg) that allows to minimize PM production [13]. Filter cigarettes of a national brand ("MS" filter cigarettes produced by Italian State Monopoly) were used, with a nicotine content of 1 mg and a tar content of 11.2 mg. The cigarettes were left smoldering at the same location as the exhaust mouthpiece, three meters from the analyser that was placed at an height of 1.5 meters.
Particulate matter was measured with a portable, laser-operated aerosol mass analyzer (Aerocet 531, Metone Instruments Inc., USA) with readings every two minutes. The instrument calculates PM_{10}, $PM_{2.5}$ and PM_1 concentrations, expressed in µg/m^3. The sensor is factory calibrated using PLS (polystirene latex) calibration particles but, since differences in the morphology, composition, temperature, humidity and optical characteristics of the aerosol to be measured can introduce errors, a re-calibration for ETS was performed by comparison with gravimetric determination according to the norms in use presently in Italy (Appendix 2 of D.P.C.M. 28/03/1983)[14].
Even though official limits have not yet set for PM_1, its concentrations are reported in detail because it's closer to the class of ultrafine particles especially dangerous to the lung, and because it is present in high percentage in both ETS and exhaust gas [10,11]. Paired comparisons (diesel versus cigarettes) of repeated measurements taken every 2 minutes were evaluated by two-sided Student's t-test.
Results. The data shown in the Figure represent one set of results from three different replicates that gave overlapping data. Official (ARPA, the Italian Environmental Protection Agency) PM_{10} 24 hour average for the day in which the reported experiments were carried out were 55 µg/m^3. In the diesel experiment the background levels recorded [mean (SD)] were 15 (1), 13 (.7) and 7 (.6) µg/m^3 for PM_{10}, $PM_{2.5}$ and PM_1 respectively, while in the ETS experiment, made four hours later, the background was 36 (2), 28(1), and 14 (.8) µg/m^3 for PM_{10}, $PM_{2.5}$, and PM_1, respectively. The mean (SD) PM levels recorded in the first hour after starting the engine were 44 (9), 31 (5), and 13 (1) µg/m^3 , while mean (SD) PM in the first hour after lighting cigarettes were 343 (192), 319 (178), 168 (92) µ g/m^3 for PM_{10}, $PM_{2.5}$ and PM_1, respectively ($P<0.001$, Student's t-test, corrected for background, for comparisons between each PM class). The diesel engine increased PM levels to a maximum of doubling outdoor values, while ETS contributed to a peak of 15-fold outdoor PM concentrations. It's remarkable that PM decay after cigarette smoking was very slow, with PM_{10} concentrations over 300 µg/m^3 lasting for up to one hour (minute 42 to102, see Figure), while PM_{10} and $PM_{2.5}$ levels exceeded outdoor limits up to about one hour and a half, at the end of the experiment.
Discussion. At least regarding PM emission, ETS was shown to be a much higher source of pollution than an ecodiesel engine. In fact three cigarettes smoldering in a room of 60 m^3 with a limited air exchange, a setting commonly encountered in everyday life, were able to produce PM concentrations up to ten-fold the engine's emissions, and up to fifteen-fold PM_{10} and $PM_{2.5}$ outdoor limits, in agreement with previous data on ETS pollution observed in the hospitality industry [8,9]. The differences in background levels between the two experiments can be explained by daily fluctuations in outdoor PM, and have been taken in account for statistical evaluation.
As for the reliability of the analysis, the analyser has been calibrated using a certified reference instrument [14]. Data reproducibility can also be accounted for by the repeatability of background recordings for any single PM class in both the experiments (see Figure, time 0-40), and by the their satisfying agreement with the official PM_{10} averages, taking in account the different location of the ARPA's station (located in a place with more intense road traffic), and the fact that the official value is the 24 hour average, while the measured ones represented 40 minute average.
In a recent report by Salvi and co-workers [15], healthy nonsmoking volunteers were exposed for

one hour to PM10 concentrations of 300 µg/m^3 generated from an idling (680rpm) diesel engine (turbodiesel, year 1991): shortly after the exposure, a marked systemic and pulmonary inflammatory response was observed. This report is relevant to our data since the setting was similar, except for the employment of an old-type diesel engine with high emission rates in Salvi and co-workers' experiment, where exhaust had to be diluted with 90% air to reach the PM concentrations of 300 µg/m 3 established for their experiment. In our experiment too, PM_{10} produced by cigarettes reached concentrations persisting for one hour over 300 µg/m^3.
Although individual specificities characterize single sources of different products, combustion aerosols share many chemical components and show similar aerodynamic profiles [16]. Accordingly, it has been shown that ETS and diesel exhausts possess many common chemical components like hydrocarbons, aldehydes, nitric oxides, carbon dioxide and carbon monoxide, and are similar for PM emissions, composed primarily by particles of less than 2.5 micrometer in diameter [10,11].
Since we utilised a room with a volume similar to that encountered in many offices and homes, the present data give raise to concern since it can be envisioned that high level PM exposure generated by ETS could account for frequent subclinical episodes of short-term respiratory damage in non-smokers due to the long time spent indoors and the fact that no efficient ventilation system can control ETS currently [6,17]. The negative comparison of ETS in respect to traffic pollution can be valuable as an educational message. In addition –especially when addressed to adolescents- an emphasis could be added to the knowledge that ETS could be considered in an ecological perspective as one of the few residual contributors to air pollution [1].

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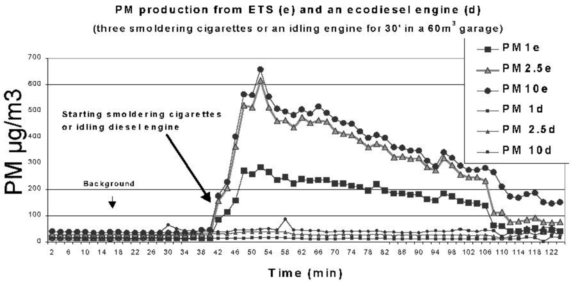

PM production from ETS (e) and an ecodiesel engine (d)
(three smoldering cigarettes or an idling engine for 30' in a 60m³ garage)
PM 1e
PM 2.5e
PM 10e
PM 1d
PM 2.5d
PM 10d
PM µg/m3
700
600
500
400
300
200
100
0
Starting smoldering cigarettes
or idling diesel engine
Background
2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82 86 90 94 98 102 106 110 114 118 122
Time (min)