

ORIGINAL RESEARCH ARTICLE

Open Access



CrossMark

# Particulate matters from diesel heavy duty trucks exhaust versus cigarettes emissions: a new educational antismoking instrument

Cinzia De Marco<sup>1\*</sup>, Ario Alberto Ruprecht<sup>1</sup>, Paolo Pozzi<sup>1</sup>, Elena Munarini<sup>1</sup>, Anna Chiara Ogliari<sup>1</sup>, Roberto Mazza<sup>2</sup> and Roberto Boffi<sup>1</sup>

## Abstract

**Background:** Indoor smoking in public places and workplaces is forbidden in Italy since 2003, but some health concerns are arising from outdoor secondhand smoke (SHS) exposure for non-smokers. One of the biggest Italian Steel Manufacturer, with several factories in Italy and abroad, the Marcegaglia Group, recently introduced the outdoor smoking ban within the perimeter of all their factories. In order to encourage their smoker employees to quit, the Marcegaglia management decided to set up an educational framework by measuring the PM<sub>1</sub>, PM<sub>2.5</sub> and PM<sub>10</sub> emissions from heavy duty trucks and to compare them with the emissions of cigarettes in an indoor controlled environment under the same conditions.

**Methods:** The exhaust pipe of two trucks powered by a diesel engine of about 13.000/14.000 cc<sup>3</sup> were connected with a flexible hose to a hole in the window of a container of 36 m<sup>3</sup> volume used as field office. The trucks operated idling for 8 min and then, after adequate office ventilation, a smoker smoked a cigarette. Particulate matter emission was thereafter analyzed.

**Results:** Cigarette pollution was much higher than the heavy duty truck one. Mean of the two tests was: PM<sub>1</sub> truck 125.0(47.0), cigarettes 231.7(90.9)  $p = 0.002$ ; PM<sub>2.5</sub> truck 250.8(98.7), cigarettes 591.8(306.1)  $p = 0.006$ ; PM<sub>10</sub> truck 255.8(52.4), cigarettes 624.0(321.6)  $p = 0.002$ .

**Conclusions:** Our findings may be important for policies that aim reducing outdoor SHS exposure. They may also help smokers to quit tobacco dependence by giving them an educational perspective that rebuts the common alibi that traffic pollution is more dangerous than cigarettes pollution.

**Keywords:** Educational perspective, Smoking cessation, Second hand smoke

## Background

Since January 2003 the Italian Government declared a national ban for cigarette smoking in indoor public places and workplaces, but nowadays some health concerns are arising from outdoor secondhand smoke (SHS) exposure for non-smokers, particularly near the public place entrances such as restaurants, bars, facilities of big industrial factories and hospital venues. Several studies in literature confirm the contribution of SHS to

the outdoor environmental pollution and to poor air quality [1–11].

Health concerns regard not only never smokers, but also smoker employees. Consequently, some companies are considering a smoking ban that encloses the outdoor places within their facilities, in order to boost smoking cessation attempts among their smokers, thus improving their health conditions.

One of the biggest Italian Steel Manufacturer, with several factories in Italy and abroad, the Marcegaglia Group, within the frame of a wider project finalized to improve the safety of its workers, recently introduced the outdoor smoking ban within the perimeter of their premise in Ravenna. The data selected for ban

\* Correspondence: cinzia.demarco@istitutotumori.mi.it

<sup>1</sup>Tobacco Control Unit, Fondazione IRCCS Istituto Nazionale dei Tumori, Milan, Italy

Full list of author information is available at the end of the article

implementation was March 21st, 2014, to highlight and transmit the message of the importance of breathing pure air in the first day of spring.

However, in order to strengthen the belief of hundreds smokers about the benefits of quitting smoking and to confer an educational perspective to their initiative, the Marcegaglia management asked for the support and trusted the experience of the Tobacco Control Unit (TCU) of the IRCCS Istituto Nazionale dei Tumori in Milan.

An educational experiment was set up.

## Methods

The first step of the TCU was to administer a questionnaire.

The questionnaire took into account gender, age, smoking habit (smoking status, number of cigarette smoked, smoking cessation attempts), attitudes toward smoking cessation activities and smoking ban proposed by the firm of all workers.

The second step was to set up an educational experiment by measuring the PM<sub>1</sub>, PM<sub>2.5</sub> and PM<sub>10</sub> emissions from a diesel heavy duty truck and to compare them with the emissions of a cigarette in an indoor controlled environment under the same conditions.

The essay was performed directly *in loco*, by the Marcegaglia Steel Factory in Ravenna. This factory is the most important center for the production and the distribution of steel products of the Marcegaglia Group and is extended over 550,000 square meters and employs over 700 workers.

The exhaust pipe of two trucks powered by a diesel engine of about 13,000/14,000cc<sup>3</sup> were connected with a flexible hose to a hole in the window of a container of 36 m<sup>3</sup> volume used as a field office. With door and window closed, the air exchange per hours (ACH) was calculated to be about 0.5/0.7.

Inside the office a fan was installed to assure the highest mixing factor as possible and one gravimetrically pre-calibrated Optical Particle Counter in mass (model Aerocon 531, Metone Instruments Inc.) was used to measure PM<sub>1</sub>, PM<sub>2.5</sub> and PM<sub>10</sub>. The gravimetric calibration of the Aerocon 531 was performed by comparison with a Beta Attenuation Monitor model BAM-1020 of Metone Instruments Inc. with US EPA EQPM-0798-122 and German T.U.V. 936/21205333/A certification for PM<sub>2.5</sub> and PM<sub>10</sub> [12]. Gravimetric calibration of PM<sub>1</sub> was not performed and the factory default gravimetric factor was used.

The heavy duty truck engines were supplied with common low sulphur diesel fuel oil purchased normally by the drivers on gas stations.

Both trucks were equipped with exhaust filters. Truck 1 had mileage of more than 1,000,000km but had recently a complete engine revision, while the Truck 2 was

almost new. Before each measurement, the truck was started and run for a while far and downwind from the field office to allow the engines to warm up in order to avoid background PM level increase inside the office because of the cold start.

In the meantime the background level of PM inside the office was measured. Then, when the engine was sufficiently warm, the truck approached the office, the engine stopped for a few minutes to allow the quick connection of the tailpipe with the flexible hose to the window inlet, the door was closed and the diesel engine was started again, run idle for 8 min and then stopped. The door was opened and the office ventilated until the background level was reached. Then a volunteer current smoker, normally working and smoking inside the office, entered and smoked two cigarettes *at libitum* for 8 min with the door closed. The cigarette brand was Marlboro.

At the end of the 8 min the door was opened and again the office was ventilated until the background level was reached again. The background outdoor level remained relatively constant during the whole duration of the tests with small concentration changes with statistically not significant difference. Both tests were repeated two times.

## Results

The results of the questionnaire showed a worrying smoking prevalence of 43 % among all workers. This value is very significant if compared to the average smoking prevalence of the Italian population, close to 20 % [13]. Fifty-six percent of the current smokers were smoking more than 20 cigarettes/day and the working place was the place where they habitually smoked more than half of the cigarettes. Despite this high prevalence of current smokers, the vast majority (>80 %) of the workers appreciated the initiative and 42 % of the smokers declared that they would like to quit.

A minority of employees, mainly smokers, criticized the outdoor smoking ban. They declared that an outdoor smoking prohibition in areas where heavy trucks continuously load and unload steel products wouldn't have reduced significantly the environmental air pollution and consequently their exposure to health hazards.

The results of the educational essay were therefore notified to all workers.

For the diesel engine/cigarettes emissions comparison two parameters were considered: a) the mean value of the background PM concentrations calculated about 8 to 10 min before starting the truck engines and/or to start to smoke the cigarettes and after the engine stop and/or stop to smoke for about 8 to 10 min after the complete washout of the office. b) the mean value of the concentrations calculated from the moment of the engines and/

or cigarettes start until the maximum peak reached before the stop.

The tests showed the following values in  $\mu\text{g}/\text{m}^3$  (SD) background subtracted:

Truck # 1: PM<sub>1</sub> truck 32.3(9.4), cigarettes 271.2(38.6)  $p = 0.003$ ; PM<sub>2.5</sub> truck 65.0(19.1), cigarettes 507.6(119.2)  $p = 0.007$ ; PM<sub>10</sub> truck 69.2(22.7), cigarettes 547.2(136.2)  $p = 0.011$  (see Fig. 1).

Truck # 2: PM<sub>1</sub> truck 218.8(86.9), cigarettes 297.0(15.2)  $p = 0.010$ ; PM<sub>2.5</sub> truck 441.5(190.0), cigarettes 1004.6(207.7)  $p = 0.006$ ; PM<sub>10</sub> truck 476.7(177.7), cigarettes 1029.5(207.7)  $p = 0.006$  (see Fig. 2). Mean of the two tests: PM<sub>1</sub> truck 125.0(47.0), cigarettes 231.7(90.9)  $p = 0.002$ ; PM<sub>2.5</sub> truck 250.8(98.7), cigarettes 591.8(306.1)  $p = 0.006$ ; PM<sub>10</sub> truck 255.8(52.4), cigarettes 624.0(321.6)  $p = 0.002$  (see Fig. 3).

## Discussion and conclusion

This study shows important data and bears educational messages.

First of all we were able to demonstrate that cigarette smoke generates more pollution in terms of PM<sub>1</sub>, PM<sub>2.5</sub> and PM<sub>10</sub> than a heavy duty truck. This finding was repeated in two tests and with two different generations of trucks, with a statistical significance ( $p < 0.05$  between cigarettes and both trucks in all PM classes).

Our findings enforce the results of a recent study, where researchers depicted the exposure levels to fine and ultrafine particles (UFP) by a bus stop, in close proximity of a smoker. PM<sub>2.5</sub> and UFP concentrations

were 16–35 and 6.2 times higher than the background concentrations due to cars and trucks on an adjacent arterial highway [14].

We have already showed that environmental tobacco smoke is a major source of PM pollution, contributing to indoor PM concentrations up to 10-fold those emitted from an idling eco-diesel engine car [15].

Involuntary exposure to secondhand or environmental tobacco smoke has been declared as carcinogenic to humans (Group 1) according to the WHO-IARC Monograph [16].

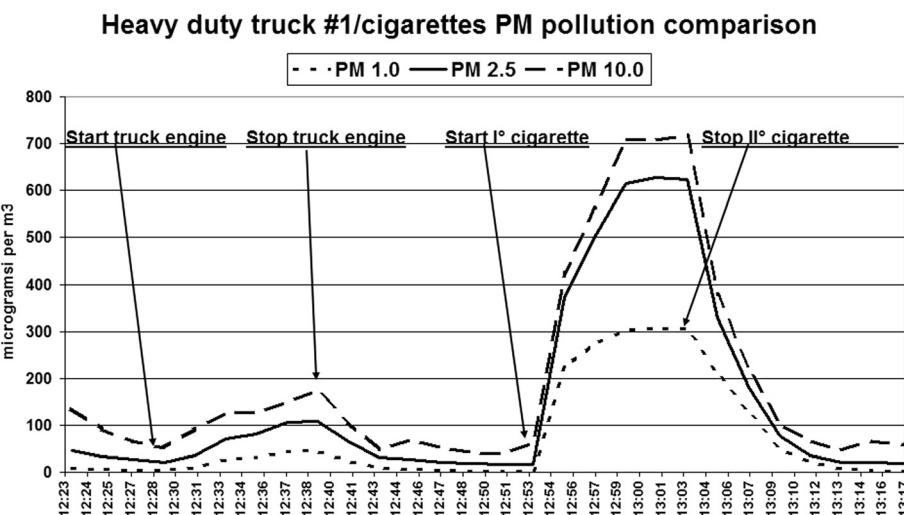
Diesel engines exhaust has also been declared carcinogenic by the same agencies [17].

Our study shows for the first time that the amplitude of peak exposure to carcinogens may be unexpectedly higher for cigarette smoke, as compared to heavy trucks, even in outdoor and occupational settings such as the one of Marcegaglia Steel Factory.

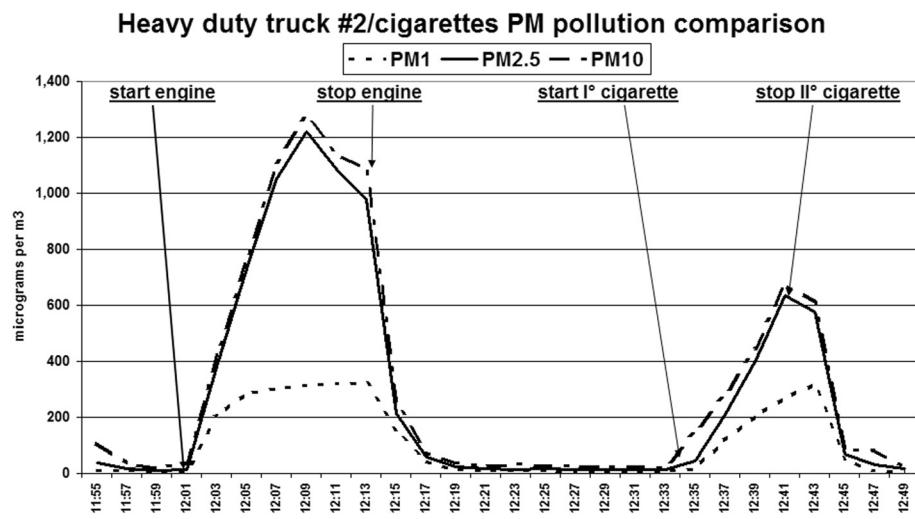
A limitation of the study may be the limited number of experiments, due to the two heavy trucks availability in a single day, when the assay was performed. Nevertheless, we believe that the shocking message and its scientific valence do not look resized even if we were not able to perform multiple analysis.

An acute inflammatory response take place in the airways and peripheral blood of humans after short-term exposure to high levels of PM produced and a consistent increased risk for cardiovascular events occurs after both short and long-term exposure to PM air pollution by diesel exhaust [18, 19]. In the light of our findings, we find even more appropriate to protect healthy workers from the hazards of outdoor smoking.

It is notable that by using the US EPA Air Quality Index calculations (available at AQI <http://>



**Fig. 1** Real time graph of the PM<sub>1</sub>, PM<sub>2.5</sub> and PM<sub>10</sub> records of test truck 1



**Fig. 2** Real time graph of the PM1, PM2.5 and PM10 records of test truck 2

[airnow.gov/index.cfm?action=aqibasics.aqi](http://airnow.gov/index.cfm?action=aqibasics.aqi)), the PM2.5 maximum concentrations reached by the truck exhaust ( $441.5 \mu\text{g}/\text{m}^3$ ) would have been classified as hazardous [20].

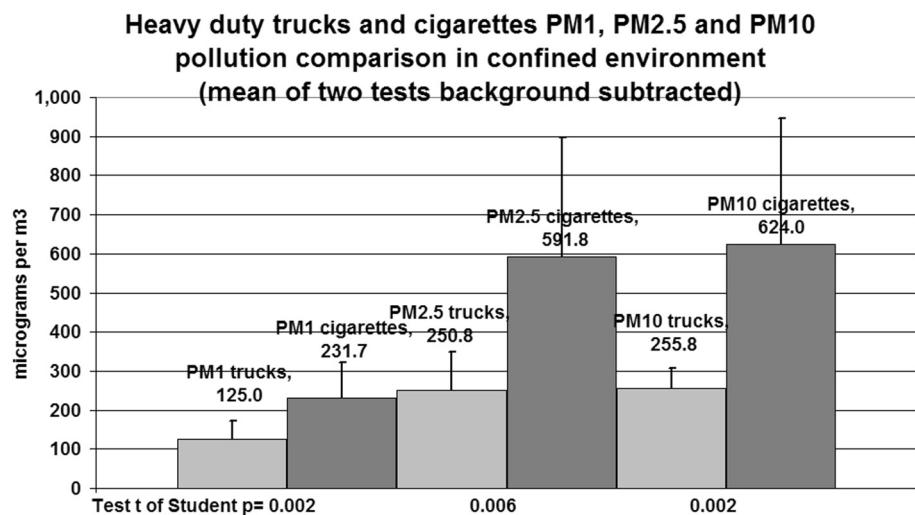
On the other hand, the cigarette maximum concentrations ( $1004.6 \mu\text{g}/\text{m}^3$ ) would have been considered out of range by this calculation because higher than  $500 \mu\text{g}/\text{m}^3$ , therefore being extremely dangerous for health [21].

Our data have been used and are still used by the Marcegaglia Ravenna's factory in health framework campaigns in order to strengthen the belief of hundreds smokers about the benefits of quitting smoking and to confer an educational perspective to their initiative.

Thanks to the Marcegaglia management a You Tube Video became available one year ago at <https://www.youtube.com/watch?v=71qxTB0uOhI> for everyone. An Editorial published on the "Eur J Paediatr Dent" has emphasized the educational importance of this study [22].

We believe that our findings may be important for policies that aim at reducing outdoor SHS exposure for sensitive categories (e.g., elderly, children, asthmatic subjects) and are intended to rebut the common alibi of smokers that traffic pollution is more dangerous than cigarettes smoking.

Initiatives such as the one here depicted may really boost the idea that quit smoking is worthless.



**Fig. 3** PM1, PM2.5 and PM10 means of the two tests background subtracted

**Competing interests**

The authors declare that they have no competing interests.

**Authors' contributions**

AAR and CDM contributed equally to draft the protocol, perform the instruments calibration and PM pollution measurements, perform the analysis, draft and submit the manuscript. RB planned the study together with the Marcegaglia Management. PP revised the manuscript. PP, EM, ACO, RM conducted the smoking cessation activities. All authors read and approved the final manuscript.

**Acknowledgements**

We are particularly grateful to Mr. Aldo Fiorini, Director of the Marcegaglia Ravenna Factory, for making available the site, the heavy truck and the office we used for the experiment and for his great commitment in the smoking cessation program finalized to improve the health conditions of all Factory employees. This paper is in memory of our colleagues and friends Giovanni Invernizzi (1949–2013) and Manel Nebot (1957–2012), with whom we shared previous investigations in this and other tobacco control topics.

**Author details**

<sup>1</sup>Tobacco Control Unit, Fondazione IRCCS Istituto Nazionale dei Tumori, Milan, Italy. <sup>2</sup>Patient Information Service, Fondazione IRCCS Istituto Nazionale dei Tumori, Milan, Italy.

Received: 9 November 2015 Accepted: 5 January 2016

Published online: 22 January 2016

**References**

1. Sureda X, Martínez-Sánchez JM, López MJ, Fu M, Agüero F, Saltó E, et al. Secondhand smoke levels in public building main entrances: outdoor and indoor PM2.5 assessment. *Tob Control*. 2012;21:543–8.
2. Boffi R, Ruprecht A, Mazza R, Ketzel M, Invernizzi G. A day at the European Respiratory Society Congress: passive smoking influences both outdoor and indoor air quality. *Eur Respir J*. 2006;27:862–3.
3. Loomis D, Grosse Y, Lauby-Secretan B, El Ghissassi F, Bouvard V, Benbrahim-Tallaa L, et al. The carcinogenicity of outdoor air pollution. *Lancet Oncol*. 2013;14:1262–3.
4. Cho H, Lee K, Hwang Y, Richardson P, Bratset H, Teeters E, et al. Outdoor tobacco smoke exposure at the perimeter of a tobacco-free university. *J Air Waste Manag Assoc*. 2014;64:863–6.
5. Congressional Research Service. Air Quality: EPA's 2013 changes to particulate matter (PM) standard. (<http://fas.org:8080/sgp/crs/misc/R42934.pdf>)
6. Acevedo-Bolton V, Ott WR, Cheng KC, Jiang RT, Klepeis NE, Hildemann LM. Controlled experiments measuring personal exposure to PM2.5 in close proximity to cigarette smoking. *Indoor Air*. 2014;24:199–212.
7. St Helen G, Bernert JT, Hall DB, Sosnoff CS, Xia Y, Balmes JR, et al. Exposure to secondhand smoke outside of a bar and a restaurant and tobacco exposure biomarkers in nonsmokers. *Environ Health Perspect*. 2012;120: 1010–6.
8. Sureda X, Fernández E, López MJ, Nebot M. Secondhand tobacco smoke exposure in open and semi-open settings: a systematic review. *Environ Health Perspect*. 2013;121(7):766–73.
9. Licht AS, Hyland A, Travers MJ, Chapman S. Secondhand smoke exposure levels in outdoor hospitality venues: a qualitative and quantitative review of the research literature. *Tob Control*. 2013;22(3):172–9.
10. Potera C. Outdoor smoking areas: does the science support a ban? *Environ Health Perspect*. 2013;121:A229.
11. Hyland A, Barnoya J, Corral JE. Smoke-free air policies: past, present and future. *Tob Control*. 2012;21:154–61.
12. Ruprecht AA, De Marco C, Boffi R, Mazza R, Lopez MJ, et al. Mass calibration and Relative Humidity compensation requirements for optical portable particulate matter monitors: the IMPASHS (Impact of smoke-free policies in EU Member States) WP2 preliminary results. *Epidemiology*. 2011;22:s206.
13. ISS-OSSFAD Rapporto Annuale sul Fumo. 2015 <http://www.iss.it/fumo/index.php?lang=1&id=346&tipo=3>
14. Ott WR, Acevedo-Bolton V, Cheng KC, Jiang RT, Klepeis NE, Hildemann LM. Outdoor fine and ultrafine particle measurements at six bus stops with smoking on two California arterial highways—Results of a pilot study. *J Air Waste Manag Assoc*. 2014;64(1):47–60.
15. Invernizzi G, Ruprecht AA, Mazza R, Rossetti E, Sasco A, Nardini S, et al. Particulate matter from tobacco versus diesel car exhaust: an educational perspective. *Tob Control*. 2004;13(3):219–21. doi:10.1136/tc.2003.005975.
16. The International Agency for Research on Cancer. Involuntary smoking (exposure to secondhand or 'environmental' tobacco smoke) is carcinogenic to humans (Group 1) Monograph 83 on involuntary smoking. IARC Monographs 2004. <http://monographs.iarc.fr/ENG/Monographs/vol83/>.
17. The International Agency for Research on Cancer of the World Health Organization. Diesel engine exhaust causes lung cancer in humans: press release N° 213 dated June 12<sup>th</sup>, 2012.
18. Salvi S, Blomberg A, Rudell B, Kelly F, Sandström T, Holgate ST, et al. Acute inflammatory responses in the airways and peripheral blood after short-term exposure to diesel exhaust in healthy human volunteers. *Am J Respir Crit Care Med*. 1999;159:702–9.
19. Brook RD, Franklin B, Cascio W, Hong Y, Howard G, Lipsett M, et al. Air pollution and cardiovascular disease a statement for healthcare professionals from the expert panel on population and prevention science of the American Heart Association. *Circulation*. 2004;109(21):2655–71.
20. Air Quality Index (AQI). A Guide to Air Quality and Your Health. <http://airnow.gov/index.cfm?action=aqibasics.aqi>
21. Whincup PH, Gilg JA, Emberson JR, Jarvis MJ, Feyerabend C, Bryant A, et al. Passive smoking and risk of coronary heart disease and stroke: prospective study with cotinine measurement. *BMJ*. 2004;329(7459):200–5.
22. Gallus S. Second-hand smoke in Italy. *Eur J Paediatr Dent*. 2015;16(4):257.

Submit your next manuscript to BioMed Central and we will help you at every step:

- We accept pre-submission inquiries
- Our selector tool helps you to find the most relevant journal
- We provide round the clock customer support
- Convenient online submission
- Thorough peer review
- Inclusion in PubMed and all major indexing services
- Maximum visibility for your research

Submit your manuscript at  
[www.biomedcentral.com/submit](http://www.biomedcentral.com/submit)

