HN. Künzli, P. Mathis, L. Oglesby, W.B. Stern
Ch. Braun, C. Monn, M. Jantunen

University Basel
Basel
Switzerland

Traffic related PM2.5 efficiently penetrate from outdoor to indoor

TRAFFIC RELATED $PM_{2.5}$ EFFICIENTLY PENETRATE FROM OUTDOOR TO INDOOR. (ELEMENTAL ANALYSES STUDY EAS-EXPOLIS).

N Künzli, P Mathys, L Oglesby, W B Stern, Ch Braun-Fahrländer, Ch Monn, M Jantunen, Institute of Social and Preventive Medicine University Basel and Inst. for Mineralogy and Petrography University of Basel, Switzerland; ETH Zurich; KTL Kuopio

Funding: *EXPOLIS:* EU contracts ENV4-CT96-0202. *EXPOLIS-EAS*: Swiss National Science Foundation contract 3200-052990.97/1 and Academy of Finland Contract 42610

Abstract

Epidemiologic studies indicate consistent associations between ambient concentrations of fine particles ($PM_{2.5}$) and health. As we spend 90% of time indoors, these associations may be plausible only if health relevant constituents of $PM_{2.5}$ efficiently penetrate indoors. The mass concentration of $PM_{2.5}$ can be considered an indicator of pollution rather than a specific pollutant. Thus the mere correlation of indoor/outdoor concentrations are not informative to address the plausibility of epidemiologic study results. To evaluate the contribution of different source categories to $PM_{2.5}$ exposure, the elemental composition of ambient air filters sampled in the framework of EXPOLIS have been analysed by energy-dispersive X-ray fluorescence spectrometry (ED-XFA). As lead may be considered a tracer for traffic, we analysed among other elements the Pb content on indoor and outdoor $PM_{2.5}$ filters.

Preliminary data from elemental analysis of indoor and outdoor filter pairs collected in EXPOLIS-Basel suggest that although in/out mass concentrations are only moderately correlated (n=45, r=0.28), the concentration of Pb on indoor and outdoor $PM_{2.5}$ is highly correlated (n=45, r=0.93). Even in the strata of smokers with a low in/out mass correlation (n=11, r=0.05) a high correlation of in/out lead concentration on $PM_{2.5}$ can be shown (n=11, r=0.95). The measured Pb outdoor concentrations were about 30% higher than the indoor concentrations ($C_{Pb\ indoor}=0.91*C_{Pb\ outdoor}-11.03$ for all participants; resp. $C_{Pb\ indoor}= 1.10*C_{Pb\ outdoor} -23.57$ for smokers).

We conclude that, although indoor sources may considerably contribute to the $PM_{2.5}$ mass concentrations, ambient $PM_{2.5}$, which epidemiologic studies suggest to be relevant for health, are not only inhaled outdoors but in similar concentrations in indoor air.

This interdisciplinary project stays in the interface of environmental science and health effect research, with relevance for policy making. The project EXPOLIS is part of the European Programme Environment and Climate; the presentation will focus on preliminary results from the Basel centre.

As discussed by P. Straehl, there is strong scientific evidence that air pollution is a contributing cause of impaired health. For inherent methodological and ethical reasons, epidemiology is the key scientific approach to assess these effects particularly if we consider long-term effects among humans. The mass concentration of particles smaller than 10μm (PM_{10}), and in fewer studies smaller than 2.5 μm ($PM_{2.5}$), has been widely used as major indicator of air pollution. In the context of this meeting two aspects are important to keep the link between recent epidemiologic evidence and future research:

1. If the existing epidemiologic studies are correct, either the mass concentration of fine particulates in ambient (outdoor) air is of health relevance *per se*, or some other PM pollution characteristic(s), which has to be highly correlated with PM mass concentration, may be of causal importance.
2. For other characteristics which are not correlated with mass concentration - as stated this morning by Prof. Heyder for the particle numbers - it may well be that they have additional independent - and not yet well investigated - effects. However, they cannot logically explain or contradict the observed associations between fine PM mass in ambient air and increased mortality or morbidity.

Epidemiologic studies show clear associations of health outcomes with the average ambient outdoor mass concentrations of PM. This has been observed both in Swiss studies, such as SCARPOL (in children) or SAPALDIA (in adults) and in many regions throughout the world. For example, SAPALDIA shows that lung function (FVC) is strongly associated with the long-term average air pollution at the residence. The Harvard Six Cities Study is one example of an epidemiologic study showing that long-term mortality increases with higher mean levels of ambient PM pollution; in other words the higher the pollution the shorter the life expectancy.
All these studies have in common that the exposure is measured on one or a few fixed ambient outdoor monitors. Accordingly two main concerns regarding the exposure in these studies are the following: First, one may argue that ambient PM measured at the fixed site monitor does not reflect the variability of personal exposure. And second, people spend most of the time indoors rather than outdoors and therefore the ambient air measurements may be considered as particularly inappropriate for estimating exposures indoors. I would like to deal with this issue in the context of EXPOLIS. EXPOLIS is the European study on population exposure distributions among the adults. In each centre (Athens, Basel, Grenoble, Helsinki, Milan, Prague) a random sample of at least 50 adults (25-55 years of age) has been selected to participate in a 48-hours exposure assessment. During this period we assessed personal exposure to several pollutants. We therefore developed a 5kg aluminium case which included among other measuring devices a BGI cyclon for $PM_{2.5}$. In addition the same pollutants have been assessed at home indoors as well as outdoors. The home indoor and outdoor measurements of $PM_{2.5}$ were conducted by standard EPA-WINS impactors. Furthermore, workplace exposure assessment were conducted. During the whole period, subjects had to provide a time activity diary with a 15-minutes resolution.

First of all, we confirmed what is well known throughout the world: personal exposure is a mixture which we get from all the microenvironments where we spend our time: Home indoor is particularly important (in average 14 hours per day). The outdoor time is rather short with a total of about 1.5 hours (Basel) and further 2 hours in transfer. The correlation between the home indoor and home outdoor $PM_{2.5}$ mass concentration is very low ($r=0.28$). Is this enough to dismiss the epidemiologic study results? One may argue that we spend most of the time indoors where the $PM_{2.5}$ exposure seems to be uncorrelated to the outdoor concentrations, measured in epidemiology. However, this argument falls short. Epidemiology shows the association of *ambient outdoor* mass concentration with several health outcomes. These studies successfully use PM mass concentration as an *indicator for outdoor air pollution* mixtures. We can however, not simply infer that indoor air PM mass concentrations stand for the same health relevant aspects of air pollution. There are very few studies focusing on the association of *indoor* or *personal* $PM_{2.5}$ mass concentration and health, thus, such an association is not established. In interpreting the epidemiologic studies on ambient air pollution, it is of importance to know whether ambient outdoor particles - consistently associated with health effects - can be found indoors as well. If penetration of the health relevant characteristics of air pollution would be very low, it would be hard to epidemiologically detect the health effects of ambient air pollution.

We chose two approaches to further assess this issue. One simple approach to test whether outdoor $PM_{2.5}$ mass concentrations are relevant indoors is by exclusion of well known indoor sources of PM pollution. This can be done in the framework of EXPOLIS because we know the time activity diary. Excluding the smoking households from the data, the indoor/outdoor correlation of $PM_{2.5}$ increases from the weak $r=0.28$ to a much higher $r=0,68$. Further exclusions of PM relevant indoor activities (such as cooking or having visiting smokers etc.) steadily increases the indoor/outdoor correlation of the mass concentration.

A further and more sophisticated approach to address the question of source related $PM_{2.5}$ has been adopted in the EXPOLIS II Elemental Analysis Study. We analysed the EXPOLIS filters at the laboratory of Prof. Stern, University Basel, using the energy-dispersive X-ray spectrometry, ED-XRF. We choose this method for several reasons. The technique is non destructive and the filters do not have to be treated chemically and can be used for further

analyses; the detection levels are rather low; and the technique allows analysis of about 90% of the elements (the elements between sodium and uranium in the periodic system). We show only two preliminary but promising results from this ongoing elemental analysis study. If we focus on *lead (Pb)* we observe a very high indoor/outdoor correlation. We consider lead an indicator of *ambient outdoor air pollution,* strongly related to combustion processes and especially to traffic. Therefore, according to this correlation, we may conclude that *ambient outdoor fine particles* - a key indicator used in epidemiology - efficiently penetrate indoors.

In contrast we show another element, calcium, which we do not consider a source specific element. It is rather ubiquitous: calcium is an important component of the earth's crust and therefore also contained in most of the building materials. We expect Ca to be related to both indoor and outdoor sources. In fact, the Ca contents of indoor and outdoor $PM_{2.5}$ are literally uncorrelated.

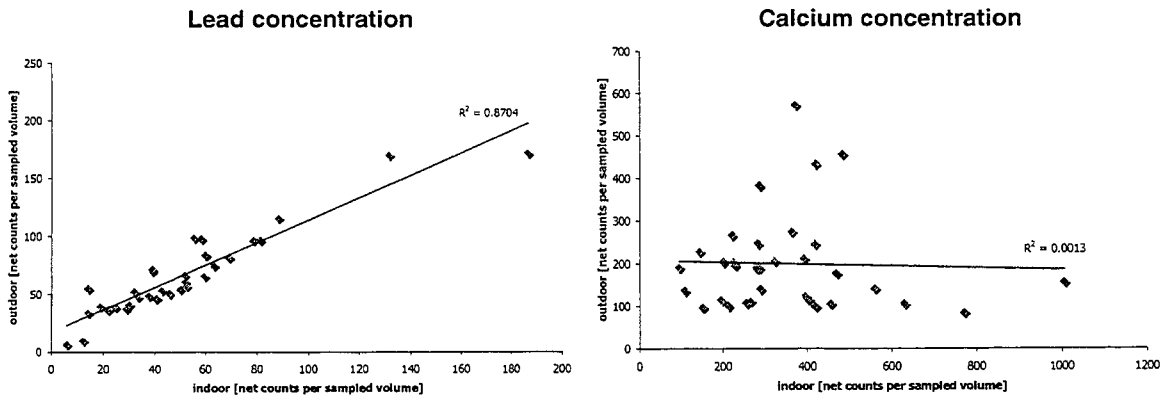

Figure 1: Indoor/outdoor correlation of lead and calcium

In conclusion, ambient $PM_{2.5}$ concentrations seem to be a reasonably good proxy measure of people's exposure to the ambient fraction of personal $PM_{2.5}$. Ambient fine particle pollution seems to penetrate efficiently indoors and therefore the time spent indoors may have a rather limited impact on the *personal* exposure to the ambient fraction $PM_{2.5}$ pollution.

These findings have to be confirmed in other EXPOLIS centres. It will be of great interest to assess the patterns of source specific elements across the European cities.