Open Journal of Pediatrics, 2012, 2, 93-96 **OJPed**
http://dx.doi.org/10.4236/ojped.2012.22016 Published Online June 2012 (http://www.SciRP.org/journal/ojped/)

Are children safe indoor from outdoor air pollution? A short review

Giovanni Ghirga*, Mara Pipere

International Society of Doctors for the Environment (ISDE), Rome, Italy
Email: *gi8589pa@virgilio.it

Received 6 February 2012; revised 24 March 2012; accepted 5 April 2012

ABSTRACT

Background: Air pollution is a serious threat to children health. Given that children spend over 80% of their time indoors, understanding transport of pollutants from outdoor to indoor environments is important for assessing the impact of exposure to outdoor pollution on children health. The most common advice given during a smoke pollution episode is to stay indoors. How well this works depends on how clean the indoor air is and how pollutants from outdoor air contribute to pollutants load in indoor air. Objective: To assess the amount of outdoor air pollution coming indoors threatening children health. Methods: A Medline/EMBASE search of scientific articles was performed to evaluate the indoor-to-outdoor (I/O) concentration ratios of two main pollutants: ultrafine particles (UFP) and ozone (O_3). Result: Under infiltration condition, the highest I/O ratios (0.6 - 0.9) were usually observed for larger UFP (70 - 100 nm), while the lowest I/O ratios (0.1 - 0.4) occurred typically around 10 - 20 nm. O_3 I/O ratios vary according to air exchange and may be 0.6 - 0.8 for interiors having a large volume exchange with outdoor air (*i.e.* open windows) and 0.3 - 0.4 with conventional air conditioning systems. Conclusions: In the absence of indoor sources or activities, indoor UFP particles originate from outdoors. O_3 concentration indoors may reach concentration similar to outdoors. Environmental and energy policies must also explicitly account for all the impacts of fossil fuel combustion on child health and development.

Keywords: Indoor Pollution; Ultrafine Particulates; Ozone; Outdoor Pollution

1. BACKGROUNDS

Fine particles (FP, aerodynamic diameter 0.1 - 2.5 micron), polycyclic aromatic hydrocarbons, sulfur and nitrogen oxides, benzene, mercury and other pollutants emitted by fossil fuel combustion (coal-burning power plants, waste incinerators, and diesel and gasoline-powered vehicles) have been variously linked to infant mortality, lower birth weight, deficits in lung function, respiratory symptoms, childhood asthma, developmental disorders, and cancer [1-8].

A recent analysis of 200 scientific articles showed that ultrafine particles (UFP, aerodynamic diameter less than 0.1 micron) are more powerful than the coarse particle fraction (CP, aerodynamic diameter 2.5 - 10 micron) and FP in inducing adverse effects to human health [9]. Unfortunately, the study of mechanisms of action of these particles presents particular difficulties because of the large number of chemical and biological mechanisms that come into play in the body after exposure to ultrafine particles.

High concentrations of UFP near major freeways have been reported recently [10-13]. These results imply increased exposure to harmful pollutants in areas close to such hot spots.

Pollutants of outdoor origin, including those present in the outdoor air and those released from soil sources, can be transported indoors via building openings and cracks [14-16].

Many urban residences and business are located in close proximity to busy roadways. Consequently, indoor environments in urban areas may experience significant concentrations of outdoor fine and UFP, exposing tenants to potentially toxic pollutants.

On average, the UFP number concentrations contribute more than 90% of the total particle number concentrations in the urban atmosphere and about 70% - 80% in the suburban atmosphere. Close to a major road, the total particle number concentrations may consist of 95% of UFP [17].

Ozone (O_3) is a polluting gas not emitted directly into the air, but at ground-level is created by a chemical reaction between oxides of nitrogen (NO_x) and volatile organic compounds (VOC) in the presence of sunlight.

Ozone causes premature deaths, chronic bronchitis, nonfatal heart attacks, hospital and emergency room vis-

*Corresponding author.

its, acute bronchitis, upper and lower respiratory symptoms, and worsening asthma [18].

Children spend most of their time approximately 80% indoors and consequently the level of indoor pollution can be critical in determining the total exposure of a child to air pollutants [19], nationwide initiatives to evaluate such indoor air quality (IAQ) were developed in the USA [20].

Stay indoors as much as you can during days when pollution levels are high is the most common advice given during a smoke pollution episode [21]. How well this works depends on how clean the indoor air is and how pollutants from outdoor air contribute to pollutants load in indoor air.

2. OBJECTIVES

To assess the burden to indoor air pollution from outdoor source of UFP and O_3 *based* on the scientific literature.

3. METHODS

Medline/EMBASE search was performed for studies evaluating the indoor-to-outdoor particle concentration ratios of two main pollutants: UFP and O_3. We retrieved 24 articles but considered relevant only five.

4. RESULTS

The relationship of indoor to outdoor concentrations for UFP and O_3 have complex characteristics but also have been fairly well studied.

The infiltration factor (INF), defined as the equilibrium fraction of ambient particles that penetrate indoors and remain suspended and the indoor to outdoor (I/O) ratios defined as the ratios of the indoor aerosol particle concentrations to that outdoors after elimination of the time-lag between their temporal variations, are used to investigate the relationship between indoor and outdoor aerosol UFP particle concentrations. Five parameters control both the INF and I/O ratios: outdoor UFP concentrations, the air exchange rate between the indoor air and the outdoor air, the deposition rate of aerosol particles, particle physico-chemical characteristics, and the penetration factor.

Although experiments have been performed to investtigate penetration properties of sub-micrometer particles, these laboratory-based studies have assumed that particles are spherical and rigid [22]. Results indicated that particle size and dimensions of cracks in deteriorated buildings were the most important factors determining particle penetration. *The latter is particularly disturbing because most of poor people lives in old building with cracks and old windows*.

The time-lag between the temporal variations of indoor and outdoor particle number concentrations can be neglected in the I/O analysis when the ventilation rate is relatively high (>2 h^{-1})·s. However, in naturally ventilated dwellings the ventilation rate is not constant and therefore the time-lag is variable in time [23] and is about of 0.5 - 3 h [24].

I/O ratios showed a strong dependence on particle sizes and were influenced by different ventilation mechanisms. The penetration factor (PF) is the most important factor in the indoor-outdoor relationship of aerosol particle concentrations. Under infiltration conditions with air exchange rates ranging from 0.31 to 1.11 h^{-1}, the highest I/O ratios (0.6 - 0.9) were usually found for larger ultrafine particles (70 - 100 nm), while the lowest I/O ratios (0.1 - 0.4) were observed for particulate matter of 10 - 20 nm [25]. The size distributions of indoor aerosols showed less variability than those of outdoor aerosols.

O_3 is a highly reactive pollutant, and for this reason I/O ratios vary according to air exchange and may be 0.6 - 0.8 for interiors with ventilation systems having a large volume exchange with outdoor air, 0.3 - 0.4 with conventional air conditioning systems, and as low as 0.02 - 0.2 with restricted ventilation or charcoal filter systems [26].

5. CONCLUSIONS

In the absence of indoor sources or activities, indoor particles originate from outdoors and their number concentrations were found to follow similar temporal variations as those encountered outdoors [17]. The ratio between indoor and outdoor concentrations is highest for ultrafine particles. The common advice given during a smoke pollution episode to stay indoors can reduce pollutant exposition but may mislead members of the public into thinking that there are no pollutants risk for children (as for other groups at risk) if they are indoor when in fact pollutants levels are high and it is well accepted that there is no "safe" threshold for fine/ultrafine particles below which no health effect occurs [26].

Globally, indoor air pollution from solid fuel use is responsible for 1.6 million deaths due to pneumonia, chronic respiratory disease and lung cancer, with the overall disease burden exceeding the burden from outdoor air pollution fivefold [27]. The quote of this health burden caused by indoor air pollution from outdoor air pollution is unknown.

A more strong intervention at reducing pollutants exposure by decreasing fossil fuel combustion processes, the main cause of UFP, should be endorsed by all countries.

REFERENCES

[1] Bobak, M. and Leon, D.A. (1992) Air pollution and in-

fant mortality in the Czech Republic. *Lancet*, **340**, 1010-1014. doi:10.1016/0140-6736(92)93017-H

[2] Gauderman, W.J., Avol, E., Gilliland, F., Vora, H., Thomas, D. and Berhane, K. (2004) The effect of air pollution on lung development from 10 to 18 years of age N. *New England Journal of Medicine*, **351**, 1057-1067. doi:10.1056/NEJMoa040610

[3] Grandjean, P. and Landrigan, P.J. (2006) Developmental neurotoxicity of industrial chemicals. *Lancet*, **368**, 2167-2178. doi:10.1016/S0140-6736(06)69665-7

[4] Ha, E.H., Lee, J.T., Kim, H., Hong, Y.C., Lee, B.E. and Park, H.S. (2003) Infant susceptibility of mortality to air pollution in Seoul, South Korea. *Pediatrics*, **111**, 284-290. doi:10.1542/peds.111.2.284

[5] Miller, R.L., Garfinkel, R., Horton, M., Camann, D., Perera, F.P. and Whyatt, R.M. (2004) Polycyclic aromatic hydrocarbons, environmental tobacco smoke, and respiratory symptoms in an inner-city birth cohort. *Chest*, **126**, 1071-1078. doi:10.1378/chest.126.4.1071

[6] Perera, F., Viswanathan, S., Whyatt, R., Tang, D., Miller, R.L. and Rauh, V. (2006) Children's environmental health research—Highlights from the Columbia Center for Children's Environmental Health. *Annals of the New York Academy of Sciences*, **1076**, 15-28. doi:10.1196/annals.1371.018

[7] Šrám, R.J., Binková, B., Dejmek, J. and Bobak, M. (2005) Ambient air pollution and pregnancy outcomes: A review of the literature. *Environmental Health Perspectives*, **113**, 375-382. doi:10.1289/ehp.6362

[8] Woodruff, T.J., Grillo, J. and Schoendorf, K.C. (1997) The relationship between selected causes of postneonatal infant mortality and particulate air pollution in the United States. *Environmental Health Perspectives*, **105**, 608-612. doi:10.1289/ehp.97105608

[9] Pedata, P., Garzillo, E.M. and Sannolo, N. (2010) Ultrafine particles and effects on the body: Review of the literature. *Giornale Italiano di Medicina del Lavoro ed Ergonomia*, **32**, 23-31.

[10] Oberdorster, G. and Utell, M.J. (2002) Ultrafine particles in the urban air: To the respiratory tract—And beyond? *Environmental Health Perspectives*, **110**, A440-A441.

[11] Reponen, T., Grinshpun, S.A., Trakumas, S., Martuzevicius, D., Wang, Z.M., LeMasters, G., Lockey, J.E. and Biswas, P. (2003) Concentration gradient patterns of aerosol particles near interstate highways in the Greater Cincinnati airshed. *Journal of Environmental Monitoring*, **5**, 557-562. doi:10.1039/b303557c

[12] Zhu, Y., Hinds, W.C., Kim, S., Shen, S. and Sioutas, C. (2002) Study of ultrafine particles near a major highway with heavy-duty diesel traffic. *Atmospheric Environment*, **36**, 4323-4335. doi:10.1016/S1352-2310(02)00354-0

[13] Zhu, Y., Hinds, W.C., Kim, S. and Sioutas, C. (2002) Concentration and size distribution of ultrafine particles near a major highway. *Journal of Air and Waste Management Association*, **52**, 1032-1042. doi:10.1080/10473289.2002.10470842

[14] Garbesi, K., Robinson, A.L., Sextro, R.G. and Nazaroff, W.W. (1999) Radon entry into houses: The importance of scale-dependent permeability. *Health Physics*, **77**, 183-191. doi:10.1097/00004032-199908000-00008

[15] Nazaroff, W.W. and Singer, B.C. (2004) Inhalation of hazardous air pollutants from environmental tobacco smoke in US residences. *Journal of Exposure Analysis and Environmental Epidemiology*, **14**, S71-S77. doi:10.1038/sj.jea.7500361

[16] Long, C.M., Suh, H.H., Catalano, P.J. and Koutrakis, P. (2001) Using time- and size-resolved particulate data to quantify indoor penetration and deposition behavior. *Environmental Science & Technology*, **35**, 2089-2099. doi:10.1021/es001477d

[17] Hussein, T. (2004) Particle size characterization and the indoor-to-outdoor relationship of atmospheric aerosols in Helsinki. *Scandinavian Journal of Work, Environment & Health*, **30**, 54-62.

[18] EPA (2010) Groun-level ozone. http://www.epa.gov/air/ozonepollution/

[19] Jenkins, P.L., Phillips, T.J., Mulberg, E.J. and Hui, S.P. (1992) Activity patterns of Californians—Use of and proximity to indoor pollutant sources. *Atmospheric Environment*, **26**, 2141-2148. doi:10.1016/0960-1686(92)90402-7

[20] Colome, S.D., Kado, N.Y., Jaques, P. and Kleinman, M. (1992) Indoor outdoor air-pollution relations—Particulate matter less than 10 Mu in aerodynamic diameter (Pm-10) in homes of Asthmatics. *Atmospheric Environment*, **26**, 2173-2178. doi:10.1016/0960-1686(92)90405-A

[21] Moglia, D., Smith, A., MacIntosh, D.L., *et al.* (2006) Prevalence and implementation of IAQ programs in US schools. *Environmental Health Perspectives*, **114**, 141-146.

[22] American Academy of Family Physicians (2011) Air Pollution. (http://familydoctor.org/online/famdocen/home/common/asthma/triggers/085.html).

[23] Liu, D.L. and Nazaroff, W.W. (2003) Particle penetration through building cracks. *Aerosol Science and Technology*, **37**, 565-573. doi:10.1080/02786820300927

[24] Franck, U., *et al*. (2006) Indoor and outdoor submicrometer particles: Exposure and epidemiologic relevance ("The 3 Indoor Ls"). *Environmental Toxicology*, **21**, 606-613. doi:10.1002/tox.20224

[25] Zhu, Y., Hinds, W.C., Krudysz, M., Kuhn, T., Froines, J. and Sioutas, C. (2005) Penetration of freeway ultrafine particles into indoor environments. *Journal of Aerosol Science*, **36**, 303-322. doi:10.1016/j.jaerosci.2004.09.007

[26] World Health Organization (2004) Indoor air pollution and health. Fact sheet No. 292. June 2005. 2nd Edition, World Health Organization, Air Quality Guidelines for Europe, WHO Regional Publications European Series No. 91.

[27] World Health Organization (2005) WHO air quality guidelines for particulate matter, ozone, nitrose dioxide and sulfur dioxide.

Abbreviations

UFP: ultrafine particles;
O_3: ozone;
FP: fine particles;
NO_x: oxides of nitrogen;
VOC: volatile organic compounds;
IAQ: indoor air quality;
I/O: indoor to outdoor;
PF: penetration factor.

