Exposure Assessment of Respirable Particle Mass and Nanoparticle Number Concentrations in Metal Processing Workplaces

Wei-Lun Chang, Yun-Hua Lin, Yi-Ting Wang, Hung-Chieh Hsu, Yi-Jyun Liou, Ching-Hui Lin, Ta-Yuan Chang, Li-Hao Young*

Department of Occupational Safety and Health, China Medical University, Taichung 40402, Taiwan
**Corresponding Author, Tel: +886 4 22053366 Ext.6219, E-mail: lhy@mail.cmu.edu.tw*

ABSTRACT

This study aims to determine workers' personal exposure to respirable particles (< 4 μm) and to characterize the number size distributions of ambient nanoparticles (<0.1 μm) during metal processing. The selected workplaces include one precision metal processing plant, one automotive body-parts processing plant, one metal welding plant and one metal milling plant. Aluminum cyclones were used to collect respirable particles and a sequential mobility particle sizer (SMPS) system for number size distributions. The results show that the workers' respirable particle concentrations (PM_4) were between 0.01 to 0.27 mg/m^3, which are well below the regulatory standard. The workplace nanoparticle number concentrations were between 2.03×10^4 to 1.19×10^6 cm^{-3}, equivalent or significantly higher than that in similar processes reported in earlier studies and typical ambient concentrations, with mode diameters in the size range of 10 to 50 nm. The PM_4 and N_{UF} showed negligible correlation among all the processes, except the mechanical processes in which a weak negative correlation was observed. The number size distributions of nanoparticles are easily affected by nearby strong emission sources, workers' operation procedures, emission control devices, and ventilation. As a result, it is difficult to elucidate the so-called "background" level and hence process-specific particle emission characteristics. Future exposure assessment studies are therefore recommended not to use respirable particles as a surrogate for nanoparticles, and to focus on personal exposure to workplace nanoparticles.

Keywords: metal processing, respirable particles, nanoparticles, number size distribution

INTRODUCTION

Metal processing, including preparation and fabrication, is one the basic industries in Taiwan. Hot processes and high-speed mechanical abrasion and attrition of solid materials are potential sources of suspended respirable particles as well as nanoparticles.[1,2] These particles in particular are considered more toxic than their larger counterparts due to the high deposition efficiency in the alveolar region and the large surface area for adsorption of toxic materials.[3]

Hot processes such as welding, smelting, refining, laser cutting and combustion are well-known emission sources of respirable particles and nanoparticles.[1,2,4,5] In addition, mechanical processes such as high-speed grinding and machining also produce noticeable amount of nanoparticles.[2,6] Conventionally, workers' exposure to suspended particles are largely focused on the regulatory mass component. Therefore, little attention has been given to these mechanical processes as a potential source of large numbers of nanoparticles.

With that in mind, the present study sets out to determine workers' personal exposure to respirable particles and to characterize the number size distributions of ambient nanoparticles. The collected exposure assessment data are then used to identify influential factors and emission sources in selected metal processing plants.

FIGURES AND TABLES

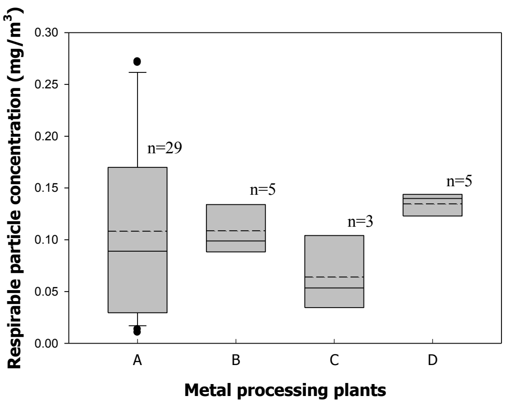

Figure 1. Respirable particle concentrations measured at the metal processing plants. The dash lines are the mean values, while the solid lines are the median values.

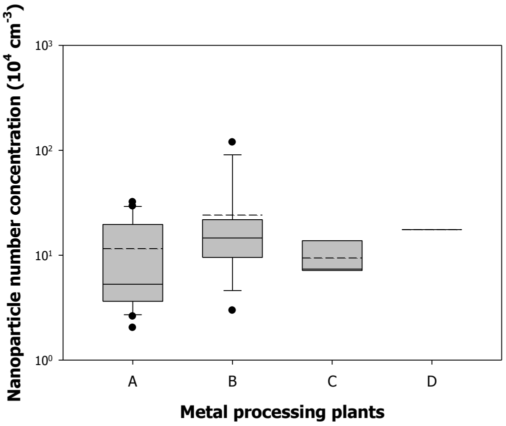

Figure 2. Ambient nanoparticle concentrations measured at the metal processing plants. The dash lines are the mean values, while the solid lines are the median values.

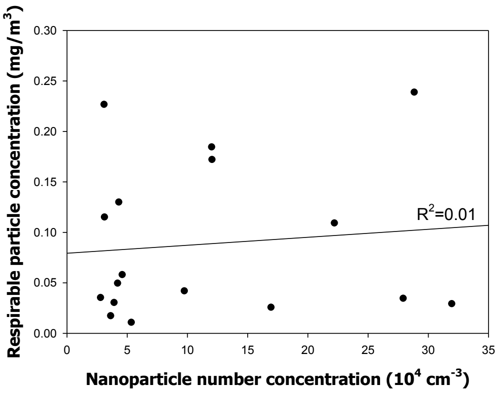

Figure 3. Correlation between the respirable particle mass and nanoparticle number concentrations measured at the A metal processing plant.

Acknowledgments

The authors would like to thank all the workers who have participated in the study. The financial support from the CMU (97-250) and NSC (97-2218-E-039-002-MY3) are gratefully acknowledged.

REFERENCES

1. Vincent, J.H.; Clement, C.F. Phil. Trans. R. Soc. A 2000. 358, 2673-2682.
2. Elihn, K.; Berg, P. Ann. Occup. Hyg. 2009, 53, 475-484.
3. Nel, A.; Xia, T.; Mädler, L.; Li, N. Science 2006, 311, 622-627.
4. Cheng, Y.H.; Chao, Y.C.; Wu, C.H.; Tsai, C.J.; Uang, S.N.; Shih, T.S. J. Hazard. Mater. 2008. 158, 124-130.
5. Demou, E.; Mutamba, G.; Wyss, F.; Hellweg, S. Indoor Built Environ. 2009, 18, 514-523.
6. Zimmer, A.T.; Maynard, A.D. Ann. Occup. Hyg. 2002, 46, 663-672.