Metal composition of ambient $PM_{2.5}$ influences the pulmonary function of school children: Case study of school children living in the nearby of an electric arc furnace factory in central Taiwan

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Electric arc furnace (EAF) steelmaking is an important production process in the Taiwanese steel industry. However, it is known that during the steelmaking process, the intense heat created by the EAF causes the molten steel to boil, which leads to the evaporation of toxic elements from the raw materials. Many studies have indicated that fine dust generated from the EAF includes toxic elements such as Fe, Zn, Ni, Pb, Cd, Cr, As (Havlik et al., 2005).

In vitro, in vivo and epidemiological studies have demonstrated that transition metal particles from high temperature combustion process and high temperature pyrolysis can exert toxicological activity [Gavett et al., 2003]. Transition metals, acting as catalyst, can generate hydroxyl radical (•OH) via the Fenton reaction, which, in turn, increase reactive oxygen species (ROS) and cause harmful health effects. Study of the relationship between ROS and individual transition metals showed that water soluble metals including Cd, Co, Cu, Fe, Mn, and Ni have good correlation with ROS concentration [See et al., 2007]. Notably, ROS can induce airway inflammation either by way of inducing apoptosis and necrosis of pulmonary cells or by enhancing transcription of proinflammatory mediators [van Eden and Hogg, 2002]. Therefore, it is suggested that chronically exposed to transition metal particles can have the potential to affect the performance of lung function, negatively [Hogervorst et al., 2006].

The current study specifically selected three primary schools in the vicinity of a large EAF steel factory in central Taiwan as study sites, where schools A and B were located closer to the EAF steel factory and downwind relative to the prevailing wind, and school C was located further away from the factory and upwind relative to the prevailing wind (control site). Air quality, specifically in terms of $PM_{2.5}$ concentrations was monitored at each site, and concentrations of nine metals (Al, As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn) in the $PM_{2.5}$ were analyzed; concurrently, the pulmonary function of schoolchildren at the three selected schools was assessed.

The results showed that the mass concentrations of $PM_{2.5}$ in exposure areas were not significantly higher than the samples taken at a control area. However, the concentrations of five metal elements, Cd, Cr, Cu, Ni, and Zn in $PM_{2.5}$ were increased with decreasing distance from the emission source. The pulmonary function tests showed that the average forced vital capacity (FVC) of boys was decreased with decreasing distance from the EAF factory. With normalization of pulmonary function by age, height and weight, we found that the △FVC became more negative with a decrease in distance from the EAF.

Table 1. Analysis of nine toxic metal concentrations in $PM_{2.5}$ collected at the three sampling sites

Element	Site A	Site B	Site C	p-value
Al	75.3±21.0	68.2±30.2	54.8±15.4	0.11
As	2.6±2.6	1.9±1.9	2.0±2.0	0.32
Cd	1.4±1.4	0.7±0.7	0.5±0.5	**0.05**
Cr	2.2±0.9	1.8±0.5	1.2±0.2	**<0.001**
Cu	21.4±12.1	19.7±14.4	8.5±3.7	**0.02**
Hg	0.2±0.1	0.2±0.2	0.1±0.0	0.06
Ni	6.8±6.6	3.5±1.3	2.4±1.2	0.02
Pb	105.5±102.7	120.6±130.0	41.0±61.2	0.09
Zn	302.7±195	221.8±201.3	55.8±24.7	**0.002**

Unit：ng/m^3

Table 2. Comparison of actual and predicted values of pulmonary function of the three sampling sites

Location	△FVC	$△FEV_1$
Boys		
A	–0.09	–0.06
B	–0.05	0.008
C	0.24	0.12
p-value	**0.006**	0.056
Girls		
A	–0.16	–0.058
B	–0.06	–0.058
C	–0.02	–0.016
p-value	0.278	0.848

$△FVC = FVC_{(actual\ value)} - FVC_{(predicted\ value)}$

$△FEV_1 = FEV_{1(actual\ value)} - FEV_{1(predicted\ value)}$

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Gavett, S.H., Haykal-Coates, N., Copeland, L.B., Heinrich, J., Gilmour, M.I. (2003) *Environ. Health Perspect.* **111**, 1471-1477.

Havlik, T., Turzakova, M., Stopic, S., Friedrich, B. (2005) *Hydrometallurgy* **77,** 41-50.

Hogervorst, J.G.F., de Kok, T.M.C.M., Briedé, J.J., Wesseling, G., Kleinjans, J.C.S., van Schayck, C.P. (2006) *J. Toxicol. Environ. Health A* **69**, 245-262.

See, S.W., Wang, Y.H., Balasubramanian, R. (2007) *Environ. Res.* **103**, 317-324.

van Eeden, S.F., Hogg, J.C. (2002) *J. Toxicol. Environ. Health A* **65**, 1597-1613.