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Birth outcomes of infants born in areas with elevated ambient exposure to incinerator generated PCDD/Fs

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Abstract

The purpose of this study was to determine if elevated ambient exposure to incinerator generated polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs) may affect birth outcomes of exposed infants born in Taipei metropolitan areas, Taiwan. The relationships between exposure to elevated PCDD/Fs concentration and various birth outcomes including birth weight, gestational age, and proportion of females were cross-sectionally assessed in 1991 (one year before the incinerator started to operate) and 1997 (five years later), respectively. We used the US EPA Industrial Source Complex Model-Sort Term modeling technique to determine the ambient PCDD/Fs concentrations in the study areas, in which 40 districts with annual averaged PCDD/Fs exposure of ≥ 0.03 pg TEQ/m^3 were considered as the exposed areas and another 40 districts with an estimated concentration of zero were randomly selected as reference areas. Information on birth outcomes was retrieved from the Taiwan's Birth Registry. A total of 6697 and 6282 neonates were included in the analysis for 1991 and 1997, respectively. After controlling for potential confounders, the results showed that the odds ratios (ORs) of low birth weight (<2500 g) for higher exposures were 0.94 (>0.05 pg TEQ/m^3) and 091 (0.03–0.05 pg TEQ/m^3) in 1991 and were 1.07 (>0.05 pg TEQ/m^3) and 1.06 (0.03–0.05 pg TEQ/m^3) in 1997. The corresponding ORs were 1.05/0.86 (1991) and 1.12/1.22 (1997) for preterm (<37 completed weeks of gestation), as well as 0.95/1.00 (1991) and 0.95/0.90 (1997) for female births. The above ORs were all close to unity and were statistically insignificant. When birth weight was analyzed as a continuous variable, the difference in mean birth weight between exposed group (>0.03 pg TEQ/m^3) and reference group decreased from 3.02 g in 1991 to −5.87 g in 1997. Analysis of continuous data also showed that the mean difference in gestational age between exposed and reference areas decreased from 0.05 weeks in 1991 to −0.09 week ($p<0.05$) in 1997. This study tends to conclude that the incinerator generated dioxin poses little effects on birth weight and female birth, but might pose small effects on gestational age. If the observed adverse effects turn out to be real, the measures now taken for improvement of abatement of waste gases seem to be a wise thing to do.

Keywords: PCDD/Fs; Exposure assessment; Adverse birth outcomes; Low birth weight

1. Introduction

The adverse effects from exposure to dioxin are well documented. Exposure to dioxin may result in increased risks of cancer mortality and morbidity (Bertazzi et al., 1989; Peterson et al., 1993). Additionally, dioxin may pose effects on thyroid hormone (Pluim et al., 1993), immunological functioning (Tryphonas, 1998), neurological development (Huisman et al., 1995), and chromosomal aberrations in humans (Huttner et al., 1999). Moreover, a change in sex ratio was observed for parents highly exposed to polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs) (Di Domenico et al., 1990; Mocarelli et al., 1999). Some studies suggested a link between persistent organochlorine compounds or PCDD/Fs and adverse reproductive outcomes including lower birth weight (Rylander et al., 1995, 1996, 2000) and preterm delivery (Mastroiacovo et al., 1988). These hazardous birth effects may be associated with decreased placental EGF-stimulated receptor autophosphorylation capacity in utero caused by dioxin (Sunahara et al., 1987). However, inconsistent findings were also found in other studies (Stocjbauer et al., 1988; Michalek et al., 1998; Patandin et al.,

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1998; Eskenazi et al., 2003; Lawson et al., 2004). Nevertheless, the World Health Organization has now recommended that the tolerable daily intake for people should be reduced from 10 pg TEQ/day/kg body weight to a lower range of 1–4 pg TEQ/day/kg body weight (WHO, 1998).

In developed countries, a large annual release of PCDD/Fs has been attributed to operation of municipal solid waste incinerators due to inappropriate management of waste gas (Eduljee and Dyke, 1996). Many governments have recently reduced national inventories of PCDD/Fs emissions into the air through tighter emission regulation. In Taipei, the capital of Taiwan, a municipal solid waste incinerator was first installed in 1992. In order to comply with the local regulation of 0.1 ng dioxin toxic equivalent (abbreviated hereafter as TEQ/m^3) effect since 2001, the incinerator was forced to shut down in 1999 for refurbishing the plant and improving abatement of waste gases. The study aims to investigate, using birth registry data of Taipei and the modeling data of PCDD/Fs concentration in the air, whether elevated exposure to ambient incinerator generated PCDD/Fs may pose effects on various birth outcomes including low birth weight (<2500 g), preterm delivery (<37 completed weeks of gestation), and sex ratio, and also studied birth weight and gestational age in general.

2. Methods

2.1. Emission source of PCDD/Fs and study design

This study considered a municipal waste incinerator, which started to operate in 1992 and placed 10 km away from downtown Taipei, as the emission source of PCDD/Fs. The incinerator was designed with three combustion chambers to treat 900 tons of solid waste per day from the Taipei city. The average emission concentration of PCDD/Fs in the exhaust gas was measured as 6.47 ng TEQ/m^3 by Taiwan Environmental Protection Agency in 1997. We used a cross-sectional design to compare various birth outcomes between exposed and control areas for both 1991 (one year before the incinerator started to operate) and 1997 (5 years later), respectively.

2.2. Estimation for ambient exposure to PCDD/Fs

The study simulated the PCDD/Fs plume generated by the incinerator to estimate downwind concentration in 1997 with an air pollution dispersion model, i.e., Industrial Source Complex Model — Short Term Model ($ISCST_3$), which was presented by the US Environmental Protection Agency (USEPA, 1995). According to the emission conditions and source geometries, both ambient air concentration and surface deposition fluxes at specific receptor can be determined. The emission parameters of the dispersion model were set with a 140 °C emission temperature, a stack of 74 m high and 2 m radius, and a 15 m/s exhaust emission rate. The terrain coordinate was determined with universal transverse mercatal and 1/25 000 digital terrain model. Atmosphere stability condition was set with medium D status of type I urban for surface data. Other parameters including hourly wind speed, wind direction, temperature gradient, plume rise and stack tip downwash were all defined with the $ISCST_3$ user's guide (USEPA, 1995). The primary data simulated with the model was then linked to the geographic districts using the geographic information system ArcView GIS 3.2a for Windows (ESRI corp., USA). With the above information, we were able to determine hourly, daily, monthly, and annual averages of PCDD/Fs concentration presented with an iso-concentration graph for each administrative districts. For example, a district located in the northwestern part of the city (about 4 km away from the incinerator) was found to have the highest hourly, monthly, and annual averages of PCDD/Fs with a corresponding figure of 4.69 pg TEQ/m^3 (in June), 0.78 pg TEQ/m^3 (in May), and 0.11 pg TEQ/m^3, respectively. We selected the annual average data in this analysis since it may best represent the cumulative exposure for the area exposed.

A study conducted on ambient air monitoring with General Metal Work model PS-1 high volume sampler to collect 48-h samples indicated that the urban and rural air background concentration were

Table 1
Birth characteristics of the study participants

Characteristics	Exposure area[a] in 1991(before operation)						Exposure area in 1997 (5 years after operation)					
	Reference		0.03–0.05 pg TEQ/m^3		>0.05 pg TEQ/m^3		Reference		0.03–0.05 pg TEQ/m^3		>0.05 pg TEQ/m^3	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Gender												
Boy	1750	53.4	1385	54.5	469	53.2	1558	51.1	1221	52.5	501	53.6
Girl	1525	46.6	1154	45.5	413	46.8	1467	48.5	1102	47.4	433	46.4
Missing	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Maternal age at the time of delivery												
≥25	2746	83.8	2263	89.1	767	87.0	2653	87.8	2114	91.0	856	91.6
<25	520	15.9	268	10.6	112	12.7	370	12.2	193	8.3	77	8.3
Missing	10	0.3	8	0.3	3	0.3	2	0.0	16	0.7	1	0.1
Maternal education level												
>12 years	717	21.9	767	30.2	266	30.0	734	24.3	899	38.7	406	43.5
≤12 years	2546	77.7	1757	69.2	613	69.5	2223	73.5	1372	59.1	509	54.5
Missing	13	0.4	15	0.6	3	0.5	68	0.2	52	0.2	19	2.0
First birth												
Yes	1440	44.0	1135	44.7	385	43.7	1420	46.9	1099	47.3	474	50.7
No	1836	56.0	1400	55.1	497	56.3	1599	52.8	1223	52.7	459	49.2
Missing	0	0.0	4	0.2	0	0.0	6	0.3	1	0.0	1	0.1
Total	3276		2539		882		3025		2323		934	

[a] Exposure area is categorized with exposure level in 1997.