行政院國家科學委員會專題研究計畫　成果報告

垃圾焚化廠周邊居民戴奧辛暴露與健康狀況之流行病學研究

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中文摘要

焚化廠可能釋放重金屬與多氯戴奧辛/多氯夫喃(簡稱戴奧辛)等有害物質，流行病學研究發現焚化廠附近居民有較高的癌症風險與血液戴奧辛濃度。國內現有19 座大型都市垃圾焚化廠在運轉，地方上反對焚化廠興建與運轉的抗爭時常發生，這些焚化廠是否影響其附近居民的健康有待進一步探討。烏日垃圾資源回收廠於 2004 年 9 月正式營運，收集此廠附近居民的基本狀況並且繼續追蹤未來情形，有助於了解此廠對附近居民的長期影響。本研究之目的為收集烏日焚化廠周邊居民之基本暴露資料、與當地其他戴奧辛污染源資料，探討焚化廠周邊居民血液中戴奧辛與暴露等因子之關係。本研究利用Short Term Industrial Source Complex (ISCST3)擴散模式配合地理資訊系統，依照該廠址之氣象條件推估其影響之區域，選取最大著地濃度區的居民為暴露組、四季盛行風上風(背景)處的居民為對照組。這些居民受邀參加問卷調查與做血液戴奧辛檢驗。本研究以high-resolution gas chromatography/mass spectrometer分析 17 種戴奧辛。最後以multiple linear regression比較暴露組與對照組間戴奧辛，同時控制可能干擾因子。調查結果顯示烏日焚化廠周界之固定戴奧辛污染源很多，其中以灰鐵製造程序的戴奧辛排放量佔最高比例，焚化廠的戴奧辛排放量佔小比例；再者，比較ISCST3 模式模擬焚化廠對周界大氣戴奧辛濃度影響與周界大氣實測濃度，可知此焚化廠對周界大氣戴奧辛之貢獻量低於 5%。有 24 位居民自願參與本研究，其中 19 位來自暴露區、5 位來自對照區，這些參加者的血液戴奧辛濃度範圍為 12.63 - 35.77 pg WHO-TEQ/g lipid，平均值(標準差)為 20.02 (6.29) pg WHO-TEQ/g lipid。暴露組的血液戴奧辛顯著地低於對照組(17.90 vs. 26.44 pg WHO-TEQ/g lipid)；Multiple regression的結果顯示在控制其他相關因子以後，暴露組的血液戴奧辛仍顯著地低於對照組，而且，這些因子解釋了血液戴奧辛變異的 40% (R^2 = 0.40)。仍需進一步的流行病學持續追蹤調查此焚化廠附近的居民。

關鍵字：垃圾焚化爐、多氯戴奧辛/多氯夫喃、環境暴露、擴散模式、流行病學

Abstract

Waste incineration may emit heavy metals and incomplete combustion byproducts, and has been one of the main sources for polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). Previous studies have reported significant associations between residence near waste incinerators and increases in cancer risk and blood PCDDs/PCDFs. The Wuji municipal solid waste incinerator started operation in September, 2004. The purpose of this epidemiological study were (1) to collect baseline information of health status and blood levels of dioxins of residents living near the Wuji municipal waste incinerator and (2) to examine other emission sources of dioxins in the surrounding area. The Short Term Industrial Source Complex (ISCST3) dispersion models and geographical information system was applied to assess the impact of incineration emissions on surrounding communities. Based on the modeling, we selected adults from the communities with the potentially highest exposures as the exposed group and adults from communities with the lowest exposures as the control group. Blood concentrations of PCDDs/PCDFs were determined using high-resolution gas chromatography/mass spectrometer. Multiple linear regression models were applied to compare blood PCDDs/PCDFs and contribution of each congener between exposed and control groups, controlling for potential confounders. There were many point emission sources of PCDDs/PCDFs in the area near the WMSWI. The smelting plants emitted a large proportion of PCDDs/PCDFs in the area, and the WMSWI contributed to less than 10% of PCDDs/PCDFs emissions. In total, 24 subjects volunteered to participate in this study. Nineteen subjects came from the exposed area and five from the control area, based on the ISCST3 dispersion modeling. Blood PCDDs/PCDFs concentration ranged from 12.63 to 35.77 pg WHO-TEQ/g lipid with a mean (SD) of 20.02 (6.29) pg WHO-TEQ/g lipid. There was a significantly difference in mean blood levels of PCDDs/PCDFs between subjects from the exposed and control areas (17.90 vs. 26.44 pg WHO-TEQ/g lipid). Results of the multiple regression analysis showed that PCDDs/PCDFs (in WHO TEQ) was significantly lower in subjects from the exposed area than did subjects from the controls area, after controlling important factors. Moreover, these factors explained 40% of variability in PCDDs/PCDFs. Further assessment and follow-up of people living near this incineration plant is needed.

Keywords: municipal waste incinerator; PCDDs/PCDFs; environmental exposure; dispersion modeling; epidemiologic study

Background and Significance

Disposal of large quantities of municipal wastes has become a serious problem in many cities in Taiwan. There is an increasing trend in using incineration as an alternative way to solve the problem of waste management. Nineteen large-scale municipal waste incineration plants are currently operating in Taiwan, with four more under construction. Incinerator emissions are complex, depending on the composition of waste, design of incinerators, combustion condition, and the downstream pollution control equipment (Oppelt 1987; Sarofim and Suk 1994). Hazardous or municipal waste incineration may emit hydrogen chloride, sulfur oxides, particulate matter, nitrogen dioxide, metals, incomplete combustion byproducts, dioxins and furans (Oppelt 1987; Marty 1993). Waste incineration has been one of the main sources for polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDDs/PCDFs) (McGregor et al., 1998). There has been substantial local opposition to the construction of waste incinerators because of concern about the potential health and environmental impact.

Epidemiological studies of the potential health effects of waste incineration have been extensively reviewed by the principal investigator and colleague (Hu and Shy 2001). These studies had investigated the effects of waste incineration on reproductive health, respiratory health, and cancer risk. Overall, the studies of health effects of waste incineration among community residents showed some similar and some inconsistent results. The results for reproductive effects were conflicting. Prevalence of several respiratory symptoms was not significantly related to living in an area with a waste incinerator in studies reviewed (Gray et al., 1994; Shy et al., 1995; Lee et al., 1999; Hu et al., 2001; Hazucha et al., 2002). Regarding cancer risk, two studies found no excess in lung cancer incidence (Elliott et al., 1992), lung cancer deaths (Michelozzi et al., 1998), and laryngeal cancer incidence (Elliott et al., 1992). Nonetheless, several studies showed significantly associations between residence near waste incinerator and increases in lung cancer incidence (Elliott et al., 1996), lung cancer mortality (Biggeri et al., 1996), laryngeal cancer deaths (Michelozzi et al., 1998), childhood cancer/leukemia mortality (Knox 2000), soft-tissue sarcoma incidence (Viel et al., 2000; Comba et al., 2003), and non-Hodgkin’s lymphoma incidence (Viel et al., 2000; Floret et al., 2003). Dioxin or TCDD have been hypothesized to play an etiological role (Viel et al., 2000; Floret et al., 2003; Comba et al., 2003). Furthermore, studies have found increased higher blood PCDDs/PCDFs levels in people living near an incinerator compared to the controls (Fierens et al., 2003), increased dioxins and heavy metal levels after operation of the incinerator (Gonzalez et al., 2000), and consistent patterns of blood dioxins levels with distance from the incinerator (Park et al., 2004).

Nineteen and more municipal waste incinerators are currently or going to be functioning in Taiwan. Waste incineration may emit particulate matter, heavy metals, and incomplete combustion byproducts, such as PCDDs/PCDFs. People living near waste incineration plants are exposed to the by-products of waste incineration. Previous studies have reported increased blood levels of PCDDs/PCDFs in residents near waste incinerators and significant associations between increased cancer risk and residence near waste incinerators. However, the potential effects of incineration emissions on community residents in Taiwan are not well understood. It is important to periodically monitor the exposures to heavy metals and dioxins from incinerator emissions among people living near an incinerator. The municipal solid waste incinerator located in the town of Wuji has started operation in September, 2004. Collection of baseline health and exposure status and follow up of dioxins exposures and health among people living in this town will provide valuable information of potential effects of the incineration plant on community residents.

Specific Aims

The purpose of this epidemiological study were (1) to collect baseline information of health status and blood levels of dioxins of residents living near a municipal waste incinerator and (2) to examine other emission sources of dioxins in the surrounding area.

Methods

The Wuji municipal solid waste incineration (WMSWI) plant is located in Wuji, Taichung County. The plant has been in operation since September of 2004. It has two incinerator units, burns about 600 tons of waste per day and is quipped with semi-dry scrubbers and bag filter for treating flue gas. The incinerators are operated by one private company under the supervision of the Bureau of Environmental Protection of Taichung County.

The town of Wuji has 16 villages and 65,700 residents (as of November, 2003). The Short Term Industrial Source Complex (ISCST3) dispersion models (US Environmental Protection Agency 1995), which take into account the meteorological data, source data (characteristics of the incinerator emissions, such as the location, emission rates, physical stack height, stack gas temperature, and etc.), and receptor data, was applied to assess the impact of incineration emissions on surrounding communities. Results from the ISCST3 dispersion modeling was integrated with the geographic information system software ArcView GIS 3.3 (ESRI, Redlands, CA) and map from the Ministry of the Interior to identify communities with the potentially highest and lowest exposures to PCDDs/PCDFs from the incineration plant. According to the modeling, we planned to randomly select 20 adults from the communities with potentially highest exposures as the exposed group and another 20 adults from communities with the lowest exposures as the control group. Male and female residents aged 18-65 years of the chosen communities and with no known history of occupational exposures to dioxins were invited to participate in this study.

The town of Wuji has several industrial plants with the potential of releasing dioxins. We collected information of these plants and obtain reports of ambient dioxins monitoring data (conducted by one of the co-investigators) to assess contribution of these plants and the municipal incinerator plant to the ambient dioxins.

Blood dioxins were analyzed at the Super Micro Mass Research and Technology Center of the Cheng-Shiou University of Technology. Forty milliliters of each blood sample were used to determine lipid-based dioxin levels by an isotope dilution method similar to the US EPA Method 1316 Revision B (US Environmental Protection Agency, 1994). Briefly, lipid contents were determined by extracting the samples three times with ultra pure water, ammonia water, ethanol, ether and petroleum following the CNS 5036N6117 method, which is promulgated by the Central Standard Bureau of Taiwan. The extracted lipids were then spiked with a 20-μL standard solution of ^{13}C labeled PCDDs/PCDFs for further cleaning. The cleanup procedures included sulfuric acid washing through sulfuric silica gel, a composite column of sodium silica gel and 40% sulfuric acid silica gel column, an aluminum column, and an activated carbon column. After cleaning, the concentrated elutant with internal standard solution was prepared for determining and quantifying lipid-based PCDDs/PCDFs by a high-resolution gas chromatography (HRGC), coupled with a high-resolution mass spectrometer (HRMS). The HRGC was a Hewlett Packard 6970 Series gas chromatograph equipped with a DB-5MS (J&W Scientific, CA) fused silica capillary column (60 m, 0.25 mm ID, 0.25-μm film thickness) and splitless injection. The HRMS was a Micromass Autospec Ultima (UK) mass spectrometer with a positive electron impact (EI^+) source. The valley value defined as 2,3,7,8-TCDD smaller than 25% was required and day check verification using the 1613CS3 standard solution was performed every 12 hours. The analysis mode was selected ion monitoring (SIM) at a resolution of 10,000. The 17 congeners determined were 2,3,7,8-TCDD, 1,2,3,7,8-pentachlorinated dibenzodioxin (CDD), 2,3,4,7, 8-hexaCDD, 1,2,3,6,7,8-hexaCDD, 1,2,3,7,8,9-hexaCDD, 1,2,3,4,6,7,8-heptaCDD, 1,2,3,4,6,7,8,9-octaCDD (OCDD), 2,3,7,8-tetrachlorinated dibenzofuran (TCDF), 1,2,3,7,8-penta-CDF, 2,3,4,7,8-pentaCDF, 1,2,3,4,7,8-hexaCDF, 1,2,3,6,7,8-hexaCDF, 1,2,3,7,8,9-hexaCDF, 2,3,4,6,7,8-hexaCDF, 1,2,3,4,6,7,8-heptaCDF, 1,2,3,4,7,8,9-heptaCDF, and 1,2,3,4,6,7,8,9-octaCDF (OCDF). The World Health Organization (WHO) toxic equivalency factors (Van den Berg et al., 1998) was used to derive toxic equivalency (TEQ) of 17 congeners for each study subject.

The data analysis started with descriptive statistics for important factors. Natural logarithm or other transformation was used to enhance normality for outcomes with skewed distribution. Chi-square test or t-test was used for unadjusted comparisons of PCDDs/PCDFs (in pg WHO-TEQ/g lipid) between two groups (exposed and control) of subjects. Multiple linear regression models were applied to assess the association between exposure group and each of the continuous outcomes, controlling for potential confounders. The SAS version 9 software (SAS Institute Inc., NC, USA) was applied for the analyses. An alpha level of 0.05 was used for all statistical tests.

Results

There were several point emission sources of PCDDs/PCDFs in the area near the WMSWI, including an industrial waste incinerator and smelting plants. The smelting plants emitted a large proportion of PCDDs/PCDFs in the area, and the WMSWI contributed to less than 10% of PCDDs/PCDFs emissions.

Based on the results of ISCST3 dispersion modeling (Figure 1) and the data of ambient air PCDDs/PCDFs concentrations (from a previous study of the co-investigator), the WMSWI contributed to less than 5% of ambient PCDDs/PCDFs in its surrounding area.

In total, 24 subjects volunteered to participate in this study. Nineteen subjects came from the exposed area and 5 from the control area, based on the ISCST3 dispersion modeling. These people had no known occupational exposures to PCDDs/PCDFs. The blood PCDDs/PCDFs concentration ranged from 12.63 to 35.77 pg WHO-TEQ/g lipid with a mean (SD) of 20.02 (6.29) pg WHO-TEQ/g lipid. There was a significantly difference in mean blood levels of PCDDs/PCDFs between subjects from the exposed and control areas (17.90 vs. 26.44 pg WHO-TEQ/g lipid). Results of the multiple regression analysis showed that PCDDs/PCDFs (in WHO TEQ) was significantly lower in subjects from the exposed area than did subjects from the controls area, after controlling important factors. Furthermore, these factors explained 40% of variability in PCDDs/PCDFs, with an R^2 of 0.40 for the regression model.

Discussion

This study showed that the WMSWI presented for less than 10% of total PCDDs/PCDFs emissions for the study area. Furthermore, the WMSWI contributed to less than 5% of ambient PCDDs/PCDFs. Therefore, other sources of PCDDs/PCDFs exposures need to be taken into account when assessing the potential effects of this WMSWI on the body burden of PCDDs/PCDFs as well as health risk among people residing in its surrounding area.

In this study, the mean (SD) blood PCDDs/PCDFs concentration was 20.02 (6.29) pg WHO-TEQ/g lipid for 24 study subjects. Results of the multiple regression analysis showed that PCDDs/PCDFs was significantly lower in subjects from the exposed area than did subjects from the controls area, after controlling important factors. Furthermore, these factors explained 40% of variability in blood levels of PCDDs/PCDFs. This proportion was much larger than that found in our studies of incinerator workers in Taiwan and those reported in many previous studies. Other factors affecting the blood concentrations of PCDDs/PCDFs and accounted for the significant differences in blood PCDDs/PCDFs between the exposed and control groups needed further investigation.

There were limitations in this study. There was only a small number of participating subjects, which decreased the statistical power to detect significant differences and limited the number of covariates to be adjusted for in the regression models. Moreover, subjects volunteered to participate in this study, which made the representativeness of this study sample questionable. However, results from this study provided valuable information that merits further assessment.

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Figure 1. Air concentrations of PCDDs/PCDFs for areas surrounding the Wuji municipal solid waste incinerator, results of the ISCST3 dispersion modeling