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癌症風險之流行病學研究

計畫類別：個別型計畫
計畫編號：NSC93-2320-B-040-023-
執行期間：93 年 08 月 01 日至 94 年 07 月 31 日
執行單位：中山醫學大學口腔醫學研究所

計畫主持人：胡素婉

計畫參與人員：張簡國平、王琳麒、陳俊傑、賴怡如、鍾巧楨、應念妏、江俊達、連珮伶

報告類型：精簡報告

處理方式：本計畫可公開查詢

中　華　民　國 94 年 10 月 28 日

中文摘要

台灣地區由於人口綢密及社會經濟迅速成長，造成垃圾量急速增加，前衛生署環保局規劃設置 23 座焚化廠來解決垃圾問題。焚化廠附近的居民可能暴露於焚化廠釋放的多種有害空氣污染物質，包括重金屬、多氯戴奧辛/多氯夫喃等。垃圾焚化是多氯戴奧辛/多氯夫喃的主要來源之一，國外的流行病學研究發現焚化廠附近的居民有較高的肺癌發生率與死亡、兒童癌症與血癌死亡、軟組織癌發生率、與 non-Hodgkin's lymphoma 發生率。國內現在有 19 座大型的都市垃圾焚化廠在運轉中，這些焚化廠產生的空氣污染物質對其附近居民的健康是否有影響，有待進一步探討。本研究的目的是探討臺灣的九座大型都市垃圾焚化廠周邊地區居民的癌症死亡情形與焚化廠排放物質、多氯戴奧辛/多氯夫喃的關係。死亡資料由衛生署與內政部的死亡登記資料庫取得，周邊地區居民的暴露以三個方法評估：距離、焚化廠周界多氯戴奧辛/多氯夫喃檢測濃度、short term Industrial Source Complex (ISC3ST) dispersion models。針對焚化廠周邊地區居民(暴露地區與對照地區)算出相關時間點內的總癌症與個別癌症的標準化死亡比(standardized mortality ratio, SMR)。本研究團隊已在過去完成四座運作 10 年以上的焚化廠之周界大氣多氯戴奧辛/多氯夫喃檢測與製作等位濃度軌跡圖，並完成戴奧辛的 ISC3ST 擴散模擬。依據這些資料，針對每一座廠選取最受影響的鄉鎮區為暴露組、較不受影響且距焚化廠 5-10 公里與>=10 公里的鄉鎮區為兩個對照組，分別計算這些地區在焚化廠運轉前後幾年間的 SMR。研究結果顯示：就個別焚化廠而言，在焚化廠運轉之前與之後，暴露組的總癌症與個別癌症之 SMR 未高於對照組；且暴露組的總癌症與個別癌症 SMR 未隨著焚化廠運轉年數的增加而呈現增加的趨勢。但是，本研究有幾個研究限制，首先，雖然 ISC3ST 擴散模擬結果顯示在同一鄉鎮區內的不同地點受焚化廠戴奧辛的影響不同，但受限於死亡資料的訊息，僅能以鄉鎮區為暴露或對照的單位，可能會有 information bias；再者，許多癌症有很長的 latency，本研究的癌症死亡時間探討為焚化廠運轉後 5 年左右，尚未有足夠時間；而且，本研究除了考慮性別與年齡之外，並未控制其他可能的干擾因子，若是這些因子與居民的焚化廠戴奧辛暴露有關，則可能干擾癌症死亡與暴露之關係。台灣有很多的焚化廠的興建，因而越來越多的焚化廠附近民眾可能會面臨這些暴露及風險，將來有必要進一步的長期追蹤探討。

關鍵字：垃圾焚化爐、多氯戴奧辛/多氯夫喃、環境暴露、癌症、死亡、流行病學

Abstract

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. Waste incineration may emit particulate matter, 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 incinerator and increases in lung cancer incidence and mortality, childhood cancer/leukemia mortality, and incidence of soft-tissue sarcoma and non-Hodgkin's lymphoma. Nineteen large-scale municipal waste incinerators (MWI) are currently functioning in Taiwan, and there has been substantial local opposition to the construction of waste incinerators because of concern about the potential health and environmental impact. Moreover, the potential cancer risk of the exposures on community residents is not well understood. The purpose of this epidemiological study was to investigate cancer mortality among residents of communities near four municipal waste incineration plants in Taiwan. The specific aims were to assess the association between ambient PCDDs/PCDFs and cancer mortality and to examine the association between exposures to incineration emissions, estimated by dispersion modeling, and cancer mortality among people living in communities near an MWI. Data of mortality from cancer was collected from death registry database of the Department of Health and the Ministry of the Interior. Community residents' exposures to incinerator emitted PCDDs/PCDFs were estimated by three methods: distance of residence from the WMI, the ambient concentrations of PCDDs/PCDFs, and the short term Industrial Source Complex dispersion models. Standardized mortality ratios (SMR) for specific cancer and all cancer were calculated for the time window of interest in each of the study areas. Among the 19 large scale MWIs currently functioning in Taiwan, five have been operating for more than 10 years. We had measured the ambient air concentrations of PCDDs/PCDFs, depicted ambient PCDDs/PCDFs isopleths, and conducted air dispersion modeling of PCDDS/PCDFs emitted by these four MWIs. Comparisons of SMR for various cancers among exposed and control areas of the four studied MWIs did not showed higher SMR in exposed areas after three to five years of operation. Nor was there an increasing trend in SMR for the exposed areas in different time periods after the operation. However, several limitations inherent in this study need to be considered before any conclusion can be made. First, using towns or districts as the unit for defining exposed and control areas might have misclassified the residents' exposures to PCDDs/PCDFs emitted from incinerator. Second, this study had an ecologic design and other confounding factors were not adjusted in the analyses. Third, yearly SMR of specific cancer for the studied areas during the time window of interest were unstable and the underlying cause of death in the mortality data could have be misclassified. Lastly, many cancers have long latency period and study of short-term mortality may not find the association. Further studies with longer period of follow-up for cancer mortality among exposed and control areas are needed to clarify the effects of incinerator PCDDs/PCDFs emission on cancer mortality.

Keywords: municipal waste incinerator; PCDDs/PCDFs; environmental exposure; cancer; mortality; 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 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 (PCDD/Fs) (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. Results of epidemiological studies conducted on residents of communities with a waste incinerator and focused on cancer risk are described as follows.

Elliott et al. (1992) used the postcoded database of the Small Area Health Statistics Unit to analyze the incidence of cancers of the larynx and lung near 10 incinerators of waste solvents and oils. No excess in incidence of laryngeal or lung cancer was found, nor was there evidence of increasing cancer risk with closer proximity to the incinerators. In a later study, Elliott et al. (1996) examined cancer incidence of people living within 7.5 km of 72 municipal solid waste incinerators in Great Britain in a two-stage study. The results showed a statistically significant decline in risk for all cancers, stomach, colorectal, and lung cancer as distance from incinerators increased. In a case-control study, Biggeri et al. (1996) investigated the effects of air pollution from four sources (including shipyard, iron foundry, city center, and an incinerator) on lung cancer deaths. The incinerator was significantly related to lung cancer (excessive relative risk = 6.7 in the source) after adjusting for age, smoking habits, exposure to occupational carcinogens, and air particulate levels in the spatial models. Michelozzi et al. (1998) used the small area techniques to study mortality from cancer of liver, larynx, lung, kidney, lymphatic, and haematopoietic systems among residents within 10 km of three major sources (a waste disposal site, a municipal waste incinerator, and an oil refinery plant) of air pollution. There was no significant decline in cancer mortality with increased distance from the sources, except for laryngeal cancer in men.

Knox (2000) studied all childhood cancer deaths between 1953-1980 in Great Britain. Distance of birth and death addresses from 70 municipal waste incinerators, 307 hospital waste incinerators, and 460 landfills was used to estimate exposures. Childhood cancer/leukemia showed statistically significant excesses of migrations away from birthplaces closes to municipal waste incinerators. Viel et al. (2000) investigated incident cases of soft-tissue sarcoma and non-Hodgkin's lymphoma in residents of department of Doubs, France. There was statistically significant spatial cluster of both cancers and space-time cluster of soft tissue sarcoma around the municipal solid waste incinerator with high dioxin emissions. To further explore the effect of dioxin emissions from this incinerator on risk of non-Hodgkin's lymphoma, Floret et al. (2003) conducted a population-based

case-control study in the same study area. The results showed an odds ratio of 2.3 (95% CI = 1.4-3.8) for people living in area with the highest dioxin concentration compared to those living in area with lowest dioxin concentration. Comba et al., (2003) examined the association between incidence of soft tissue sarcoma and residence near an industrial waste incinerator in Italy using a case-control approach. The odd ratios for residence with 2 km from the incinerator compared to control area was 31.4 (95% CI = 5.6-176.1), and 2,3,7,8,-tetrachlorodibenzo-p-dioxin (TCDD) was speculated as the cause.

Overall, the studies of health effects of waste incineration among community residents showed some similar and some inconsistent results. 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). Moreover, dioxin or TCDD have been hypothesized to play an etiological role (Viel et al., 2000; Floret et al., 2003; Comba et al., 2003).

Waste incineration has been one of the main sources for polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) (McGregor et al., 1998). Many studies have investigated the potential adverse effects of PCDDs/PCDFs on human health, especially cancer risk. Cohort studies of pesticides/chemical plant workers found significantly increased risk of total cancer mortality (Flesch-Janys et al, 1998; Vena et al, 1998). Studies of Operation Ranch Hand veterans did not show significantly elevated all cancer risk (Michalek et al, 1998; Ketchum et al, 1999). Follow-up studies of Seveso residents show marginally increased mortality from all cancer and lung cancer and increased rectal cancer mortality among men and an excess in lymphohemopoietic neoplasms in both genders 15 years after the accident (Bertazzi et al, 2001). The International Agency for Research on Cancer has classified TCDD as the Group 1 carcinogen (McGregor et al, 1998). The National Toxicology Program of the US Department of Human Health Service has classified TCDD as "known to be human carcinogens" in its Ninth Report on Carcinogens (US DPHS 2001).

Nineteen and more municipal waste incinerators are going to be or currently 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 significant associations between increased cancer risk and PCDDs/PCDFs exposure or residence near waste incinerators. However, the potential health effects of incineration emissions on community residents in Taiwan are not well understood. It is important to assess the potential cancer risk from exposures to incinerator emissions, especially dioxin, among the exposed population.

Specific Aims

The purpose of this epidemiological study was to investigate the cancer mortality among residents of communities near nine municipal waste incineration plants in Taiwan. The specific aims were (1) to assess the association between ambient PCDDs/PCDFs and

cancer mortality and (2) to examine the association between exposures to incineration emissions, estimated by dispersion modeling, and cancer mortality among people living in communities near a waste incinerator.

Methods

Study municipal waste incineration plants

Nineteen large scale (>=600 tons per day) and one smaller (300 tons per day) municipal waste incineration (MWI) plants are currently operating in Taiwan. During years 2002-2003, the co-investigator (Dr. Chang-Chien) and colleagues have analyzed ambient air concentrations of PCDDs/PCDFs in nearby areas for 11 of these MWIs. The longest duration of operation was12 years and the shortest was 3 years. Considering the long latency period of cancer, only MWIs operating longer than 10 years were included in this study.

Various equipments were used in these MWIs to treat flu gas. For example, NH MWI has been equipped with semi-dry scrubbers, activated carbon injection, and bag filter since the year of 2000 (wet scrubber and electrostatic precipitator before 2000). PT MWI uses semi-dry scrubber and bag filter to treat flue gas. MC MWI is equipped with electrostatic precipitator and wet scrubber. Some of these plants have been remodeled to reduce the emissions of PCDDs/PCDFs. For example, NH MWI was upgraded during February 1999–March 2001 and MC MWI underwent its PCDD/Fs emission control project between November 2000 and April 2002.

Study population

All people living in the communities with a MWI or in communities within 10 km from the MWI were considered as the potentially exposed population. People living in the same metropolitan area or city/county but at least 10 km away from any MWI were considered control population. Since the health outcome data only have information for town/district of residence, all population of that town/district were included in this study. The population statistics, including number of people in each 5-year age-sex group in each town/district will be collected from the Department of Statistics, Ministry of the Interior and local governments.

Measurement of health outcomes

The main health outcomes include mortality from: all cancer, lung cancer, soft tissue sarcoma, and non-Hodgkin's lymphoma in adults and in all age groups and all cancer and leukemia in children. Coding from the International Classification of Diseases - 9th Revision (ICD-9) was used to classify major cause of death and cancer, including all cancer (ICD-9 codes140-208), lung cancer (ICD-9 code 162), cancer of respiratory system (ICD-9 codes 162-165), cancer of soft tissue (ICD-9 code 171), cancer of lymphatic and hematopoietic tissue (ICD-9 codes 200-208), and etc. Cancer of digestive organs and peritoneum (ICD-9 codes 150-159) were the control disease.

The mortality data was collected from the "Causes of Death" Database of the Department of Health and the "Death Registration" Database of the Ministry of the Interior. The data contains the following information: ID, sex, permanent address (town, city/county), marital status, occupation, birthday, date of death, place of death, type of death, cause of death (ICD code), supplementary classification of external causes of injury and poisoning (E-code), age, and etc.. Furthermore, many cancers have long latency periods, whereas most

of the MWIs have been operating for only three to five years. Only childhood cancer mortality was investigated for residents near these MWIs. For each of the studied MWIs, the time periods of interest were 5 years after operation. Three to five years before operation and the first five years after operation of the MWI were included as the control periods.

Exposure assessment

Community residents' exposures to incinerator emissions and PCDDs/PCDFs were estimated by three methods. Firstly, distance of residence from the WMI was used. Towns/districts located within 5 km of the MWI were classified as exposed area and those located at least 10 km from the MWI were classified as the control areas. Secondly, the ambient concentrations of PCDDs/PCDFs (expressed as of international toxic equivalents) or specific congeners, which have been measured by the co-investigator (Dr. Chang-Chien) in recent years for these MWIs, was used to estimate exposures to PCDDs/PCDFs for residents of the communities near the MWIs. Thirdly, the Short Term Industrial Source Complex (ISC3ST) 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 for each year. We conducted dispersion modeling for several of these MWIs and incorporated results from the ISCST3 dispersion modeling with the geographic information system (GIS) to identify communities with highest and lowest concentrations of air pollutants from each of the MWIs.

Date analysis

Data analysis started with management of the mortality data and the population data, which were collected from the Department of Health and the Ministry of the Interior, for the exposed towns/districts and control communities identified from the exposure assessment (by distance, ambient PCDDs/PCDFs concentrations, and dispersion modeling and GIS) mentioned above. For each of the MWIs that have been operating for more than 10 years, the time periods of interest were 5 years after operation. Three years before operation and the first three years of operation of the MWI were included as the control periods. Standardized mortality ratio (SMR) was calculated for the exposed and control areas, respectively, for the time window of interest. The mid-year population and the cause-specific mortality rates for each age categories of Taiwan in 1981 were used as the standard for adjustment. The SAS version 8.2 software (SAS Institute Inc., NC, USA) was applied for the data analyses.

Results

Among the 19 large scale MWIs currently functioning in Taiwan, five have been operating for more than 10 years. We have measured the ambient air (and soil and plant) concentrations of PCDDs/PCDFs for four of these MWIS during the past years. Ambient PCDDs/PCDFs isopleths were depicted for areas surrounding these four MWIs using ArcView software (ESRI, CA, USA). Furthermore, the ISC3ST model was applied to estimate air dispersion of PCDDS/PCDFs emitted by these four MWIS.

The exposed towns/districts and the control towns/districts were identified by their distance from the incineration plant and/or based on the results of ISC3ST modeling. For example, five towns/districts within five kilometers of TCMWI and most affected by the emissions of TCMWI were considered as the exposed areas. Two control groups were identified taking into account the population density, distance from the incinerator, and

results of ISC3ST modeling. Control-1 group consisted of towns/districts located 10 kilometers away from TCMWI and were not significantly down wind from the incinerator. Control-2 groups consisted of towns/districts located within 5-10 kilometers from the incinerator.

Observed death counts in the exposed and control towns/districts in the specified time window were calculated for all cancer, cancer (ICD-9 code 140-208), of respiratory and intrathoracic organs(ICD-9 code 160-165), lung cancer (ICD-9 code 162), cancer of bone, connective tissue, skin, and breast (ICD-9 code 170-176), cancer of lymphatic and hematopoietic tissue (ICD-9 code) in all age groups and for all cancer and cancer of lymphatic and hematopoietic tissue in children aged 14 and under. SMR were then calculated and compared among these studied areas. The yearly SMR for subjects aged 14 and under were unstable in these towns/districts, so were the three-year SMR in this age group. Therefore, we did not further compare the SMR among exposed and control areas for subjects under 15 years old.

Comparisons of SMR for various cancers among exposed and control areas of the four studied MWIs did not showed higher SMR in exposed areas after three to five years of operation. Nor was there an increasing trend in SMR for the exposed areas in different time periods after the operation. Figure 1 presents the SMR of TCMWI exposed and control areas during the three time periods. The SMR for all cancer appeared to be lower in the exposed towns/districts than in the control-1 and control-2 areas. For the control areas, SMR for all cancer did not increased 5 years after operation of the incinerator. As for respiratory cancer, SMRs were higher in the exposed areas than that in the control-1 area before operation, but they appeared to be lower in the exposed areas than in the control areas 5 years after operation.

Discussion

This study investigated the associations between exposures to incinerator emissions of PCDDs/PCDFs and cancer mortality among people living in communities near a waste incinerator in Taiwan. ISC3ST dispersion modeling and distance was used to identify towns/districts most likely to be exposed to each of the four MWIs operating for more than 10 years, while areas within 5-10 or >=10 kilometers from each of the MWIs were chosen as controls. Standardized mortality ratio was calculated for the all cancer and specific cancer for the exposed and control areas during the time period before and after operation of each MWI. The results showed that SMR for all and/or specific cancer was not higher in the exposed communities than in the control areas. Moreover, there was no increasing trend in cancer mortality for the exposed areas after five-year operation of the MWIs.

Several limitations inherent in this study need to be considered before any conclusion can be made. Firstly, using towns or districts as the unit for defining exposed and control areas might have misclassified the residents' exposures to PCDDs/PCDFs emitted from incinerator. Results from the ISC3ST dispersion modeling and ambient PCDDs/PCDFs isopleths showed that the exposures varied for different locations inside a town or district. However, the mortality data only contained the information of towns or districts for the subjects' residencies and did not provide information for more detailed address. Therefore, this study was not able to assess the effects of dioxins on cancer mortality of specific location of each towns or districts. Secondly, this study had an ecologic design and other confounding factors (except age and sex) were not adjusted in the analyses. The observed

exposure-outcome association could have been biased. However, if distributions of potential confounders among residents of each towns/districts were not associated with their exposures to incinerator emissions, these factors would not confound the association. Thirdly, yearly SMR of specific cancer for the studied areas during the time window of interest were unstable and the underlying cause of death in the mortality data could have be misclassified. Lastly, many cancers have long latency period and longer period of follow-up for cancer mortality among exposed and control areas are needed to clarify the effects of incinerator PCDDs/PCDFs emission on cancer mortality.

More incinerators are going to be functioning in Taiwan and more community residents will be exposed to the by-products, including PCDDs/PCDFs, of waste incineration. It is important to assess the potential health risk of incinerator emissions among people living near the incinerators. Further studies are needed to investigate the long-term effects of these incinerators.

References

Bertazzi PA, Conconni D, Bachetti S, Rubagotti M, Baccarelli A, Zocchetti C, Pesatori AC. Health effects of dioxin exposure: A 20-year mortality study. Am J Epidemilogy 2001;153:1031-1044.

Biggeri A, Barbone F, Lagazio C, Bovenzi M, Stanta G. Air pollution and lung cancer in Trieste, Italy: spatial analysis of risk as a function of distance from sources. Environmental Health Perspectives 1996; 104(7):750-754.

Comba P, Ascoli V, Belli S, Benedetti M, Gatti L, Ricci P et al. Risk of soft tissue sarcomas and residence in the neighbourhood of an incinerator of industrial wastes. Occupational & Environmental Medicine 2003; 60(9):680-683.

Elliott P, Hills M, Beresford J, Kleinschmidt I, Jolley D, Pattenden S et al. Incidence of cancers of the larynx and lung near incinerators of waste solvents and oils in Great Britain. Lancet 1992; 339 (8797):854-858.

Elliott P, Shaddick G, Kleinschmidt I, Jolley D, Walls P, Beresford J et al. Cancer incidence near municipal solid waste incinerators in Great Britain. British Journal of Cancer 1996; 73(5):702-710.

Flesch-Janys D, Steindorf K, Gurn P, Becher H. Estimation of the cumulated exposure to polychlorinated dibenzo-p-dioxins/furans and standardized mortality ratio analysis of cancer mortality by dose in an occupationally exposed cohort. Environmental Health Perspectives 1998;106 Suppl 2:655-62.

Floret N, Mauny F, Challier B, Arveux P, Cahn JY, Viel JF. Dioxin emissions from a solid waste incinerator and risk of non-Hodgkin lymphoma. Epidemiology 2003; 14(4):392-398.

Hu SW, Shy CM. Health effects of waste incineration: A review of epidemiological studies. Journal of the Air & Waste Management Association 2001;51:1100-1109.

Ketchum NS, Michalek JE, Burton JE. Serum dioxin and cancer in veterans of Operation Ranch Hand. Am J Epidemiol 1999;149:630-639.

Knox E. Childhood cancers, birthplaces, incinerators and landfill sites. International Journal of Epidemiology 2000; 29(3):391-397.

Marty MA. Hazardous combustion products from municipal waste incineration; Occupational Medicine 1993;8:603-620.

McGregor DB, Partensky C, Wilbourn J, Rice JM. An IARC evaluation of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans as risk factors in human carcinogenesis. Environmental Health Perspectives 1998;106 Suppl 2:755-60.

Michalek JE, Ketchum NS, Akhtar FZ. Postservice mortality of US air force veterans occupationally exposed to herbicide in Vietnam: 15-year follow-up. Am J Epidemiol 1998;148:786-792.

Michelozzi P, Fusco D, Forastiere F, Ancona C, Dell'Orco V, Perucci CA. Small area study of mortality among people living near multiple sources of air pollution. Occupational & Environmental Medicine 1998; 55(9):611-615.

Oppelt ET. Incineration of hazardous Waste. A critical review. JAPCA 1987;37:558-586.

Sarofim AF, Suk WA. Health effects of combustion by-products. Environmental Health Perspective 1994;102 Suppl 1:237-244.

U.S. Department of Health and Human Services. Public Health Service. National Toxicology Program. *Ninth Report on Carcinogens*. 2001.

US Environmental Protection Agency, 1995. *User's Guide for the Industrial Source Complex (ISC3) Dispersion Models, Volumes 1 and 2.* EPA Publication Nos. EPA–454/B–95–003a & b. U.S. Environmental Protection Agency, Research Triangle Park, NC.

Vena J, Boffetta P, Becher H, Benn T, Bueno-de-Mesquita HB, Coggon D, Colin D, Flesch-Janys D, Green L, Kauppinen T, et al. Exposure to dioxin and nonneoplastic mortality in the expanded IARC international cohort study of phenoxy herbicide and chlorophenol production workers and sprayers. Environmental Health Perspectives 1998;106 Suppl 2:645-53.

Viel JF, Arveux P, Baverel J, Cahn JY. Soft-tissue sarcoma and non-Hodgkin's lymphoma clusters around a municipal solid waste incinerator with high dioxin emission levels. American Journal of Epidemiology 2000; 152(1):13-19.

Figure 1. Standardized mortality ratios for all cancer and respiratory cancer in the exposed and control areas of TC MWI.