A SCREENING LEVEL RISK ASSESSMENT OF DIOXINS FROM A MUNICIPAL INCINERATOR IN THE TAIPEI METROPOLITAN AREA

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Introduction

Dioxin compounds are widespread environmental pollutants. Their persistency in environment and high lipophilic property render them bioaccumulating and biomagnifying through food web into different trophic levels of organisms, and subsequently into human. The major source of this groups of chemicals is municipal incinerators, which comprised more than 50% of the emission in US[1]. In recent years, municipal waste increases dramatically due to rapid economic growth in Taiwan. To resolve this problem, our government decided to have more than 90% of the municipal waste incinerated by 2004[2]. By then, there are going to have a total of 36 municipal waste incinerators (MWIs) in Taiwan, while 10 incinerators are currently in operation. In 1997, Taiwan EPA has set a stack emission standard of 0.1ng TEQ (dioxin toxic equivalent)/Nm^3 (the following dioxin concentrations are all in TEQ basis), the most stringent standard in the world, for dioxins from new municipal waste incinerators received more than 300 ton/d of waste. For the existing 10 incinerators, either retrofit or rebuild is required for incinerators not meeting the national emission standard. However, earlier investigation indicated that dioxin released from these incinerators, before any modification, were much higher than the emission standard[3]. Besides, these plants were built in suburban area in the beginning, but these areas became highly populated owing to limited land available for development in Taiwan. Health impact by dioxin emission from MWIs was of concern by local residences and environmental groups. The purpose of this study was to address this issue by conducting a screening level risk assessment.

Methodology

A MWI in the Taipei metropolitan area was selected for investigation. This MWI has been operated since 1992, but data of dioxin emission monitoring are available only at the year of 1997. There were eight flue gas samples taken by Taiwan EPA at different dates in 1997. The average concentration of each dioxin congener in the eight samples in 1997 was used to estimate dioxin exposure in the period of 7 years from 1992 to 1999. This 7-year period was designated as the Period 1 in this study. In 1999, the plant was re-constructed for compliance of the emission standard till 2000. We assume that the MWI will run for a total of 30 years, and after the reconstruction, the stack concentration of total dioxins will be 0.1ng/m^3 for the rest of the 23 years (30 minus 7), which designated as the Period 2. In the Period 2, the dioxin congener pattern is considered identical to that in the Period 1, in order to derived different congener-specific concentrations in stack emission. In this study, the Industrial Source Complex Short Term Model Version 3 (ISCST3) was used to predict dioxin concentrations at the ground level of the maximum exposure. Wet deposition was not considered in deposition models. Transportation of the dioxins via different routes into various environmental medians and human were estimated according to models summarized in a report by Zemba and his associates[4]. Seventeen dioxin congeners were considered in the TEQ scheme, and their concentrations in different media were calculated individually using congener-specific values in that report[4]. Parameters used were either default values or modified accordingly, based on availability of the data, and are outlined in Table 1. In this screening level risk assessment, in order to simplify the scenario, only three major exposure pathways were considered, namely inhalation, ingestion of contaminated soil, and leafy and exposed vegetables, as designated in Zemba's report[4]. Adults and 2.5-year old children were considered possible receptors for dioxin exposure in this study, and their corresponding lifetime average daily doses (LADD, mg/kg/d) were estimated for the final calculation of the cancer risk (R) and non-cancer risk, expressed as the hazard index (HI).

Results and Discussion

The average dioxin flue gas concentration was 6.58 ng/m^3, which was adjusted with stack humidity and oxygen concentrations. The average concentration of each individual congener was not reported here due to limited space, but was used for further estimation of the exposure in the Period 1, as defined in the methodology section. By using ISCST3, the location of the maximum exposure was identified at 0.8 km, southwest, relative to the incinerator, and the estimated dioxin concentrations for the Period 1 and 2 were 0.0281 pg/m^3 and 0.0174 pg/m^3, respectively. These values were lower than the background levels reported by USEPA[5] (0.0949 pg/m^3 in North America and 0.108 pg/m^3 in Europe). In contrast, ambient air concentrations of 0.17 and 0.35 pg/m^3 were measured at the downwind of an incinerator with the stack average dioxin level of 136 ng/m^3 [6]. Assuming only dry deposition occurring for particle-bound dioxins, dioxin concentrations in soil for the two exposure periods were 0.166 ng/kg and 0.0094 ng/kg, respectively. These values were 50~1000-fold lower than the background levels cited in the USEPA's report[5] (7.96 pg/m^3 in North America and 8.69 pg/m^3 in Europe). An urban background soil concentration of dioxins was estimated at 4 ng/kg[6]. The same study also determined soil concentrations ranging from 4 to 60 ng/kg within 2 km of an incinerator[6]. By using the estimated dioxin concentration in soil, we estimated dioxin levels in leafy and exposed vegetables for Period 1 to be 2.32 and 2.31 ng/kg (wet weight), respectively, and for Period 2 to be 0.0398 and 0.0395 ng/kg, respectively. These estimations were higher than the value in another study (0.008 ng/kg)[7]. The dioxin concentrations in vegetables in the Period 1 were at the same magnitude in plants collected near an incinerator (1.07~3.05 ng/kg, dry weight)[8]. By using the estimated values abovementioned and parameters in Table 1, we calculated the LADDs for three identified exposure pathways and associated risks for both adults and children. The results were summarized in Table 2.

For adults, ingestion of contaminated vegetables is the major pathway for long-term (30 years) exposure to dioxins, which also contributes an excess lifetime cancer risk higher than 1 in a million, the acceptable value for most regulatory agencies. Exposure during the Period 1 also accounts for more than 90% of the total cancer risk within the 30-year exposure period. The other two exposure pathways are insignificant, considering their much lesser cancer risks estimated. This consisted with our knowledge that dioxins enter human body mostly through food consumption[5]. The combined HI value from the Period 1 and 2 is less than 1, indicating an acceptable non-carcinogenic risk. For 2.5-year old children, although they consume less vegetables than adults on daily basis, their cancer risks due to ingestion of dioxin-contaminated vegetables for only 2.5 years are very close to the value for adults for the 30-year exposure. This is due to children's smaller body weights. It is also noted that even in the Period 2, the time when the dioxin emission is in compliance with the national standard of 0.1

ng/m^3, this exposure will result in a cancer risk (1.10e-6) close to the acceptable level. The HI value for children in either the Period 1 or 2 is less than 1.

This screen level risk analysis was conducted based on several assumptions and values, however, uncertainty and variability for application of different models or parameters on the case should also be examined at the sometime. Firstly, Chinese usually consume more vegetables than Americans. Using the default consumption rate for vegetables will lead to underestimate the total risk. Secondly, the soil/vegetable transportation models or parameters for dioxins may not be appropriate because of the variety of vegetables in Taiwan. Thirdly, instead of using the maximal emission rate in this baseline practice, we used the average dioxin concentrations for the estimation, which may not be appropriate for the screening level analysis. Finally, there is another MWI at 7~8 km away, due south, from the investigated MWI. Whether this will contribute an additional dioxin exposure at the maximally exposed individuals is unclear. Nevertheless, this practice showed that a more thorough and detailed risk assessment is necessary for the investigated MWI since the "worst case" approach revealed unacceptable cancer risks. The same analysis should also be employed to other MWIs to ensure better risk management.

Reference

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Table 1. Assumptions and parameter values for exposure or transportation estimation

Assumptions		
Operation time for the incinerator (yr)	30	
Operation days in a year (d)	300	
Exposure parameters	**Adult**	**Child**
Lifetime (yr)	70	2.5
Body weight (kg)	65[a]	12.75[a]
Inhalation rate (m^3/d)	20	8.6
Consumption rate of leafy vegetables (kg/d)	0.039	0.023
Consumption rate of exposed vegetables (kg/d)	0.089	0.053
Consumption rate of soil (mg/d)	100	200
Fraction of week soil contact occurs	0.286	0.714
Fraction of year soil contact occurs	0.417	0.500

Table 1 (continued)

Parameters for transportation of dioxins to soil			
Congener-specific vapor fraction		reference 4	
_d	Deposition velocity (cm/s)	0.2 (reference 9)	
_	Length of emission period (yr)	70	
_s	Soil bulk density (kg/m^3)	1500	
z	Soil mixing depth (m)	0.2	
Parameters for transportation of dioxins to vegetables		**leafy**	**exposed**
_a	Air density (kg/ m^3)	1.19	
Bvv	Congener-specific vapor uptake ratio	reference 4	
Bv or Br	Root uptake factor	0.013	0.013
r	Intercept fraction	0.1192	0.0319
y	Yield (kg/m^2), in wet weight	1.5	1
t_v	Length of growing season (yr)	0.42	0.42
d_w	Dry-to-wet weight conversion factor	0.066	0.126
k_v	Wash off coefficient (l/yr)	18	18
Toxicological parameters			
R_fC	Reference concentration (mg/m^3)	3.50e-9	
R_fD	Reference dose (mg/kg/d)	1.00e-9	
Unit risk	Unit risk (m^3/ug) for inhalation	33.4	
q_1*	Slope factor (kg-d/mg)	1.56e+5	

Values are taken from Zemba's report[4], unless specified.

[a] these values are considered as default values for Taiwanese.

Table 2. LADDs and risks for adults and 2.5-year old children due to dioxin from the incinerator.

		Period	LADD(mg/kg/d)	Cancer Risk (R)	Non-cancer risk (HI)
Adult	Inhalation	1	0.0281[a]	7.71e-08	6.60e-04
		2	0.0174[a]	4.78e-08	4.09e-04
	Ingestion vegetables	1	3.74e-10	5.83e-05	0.374
		2	2.11e-11	3.29e-06	0.0211
	Ingestion soil	1	2.50e-15	3.91e-10	2.50e-06
		2	4.66e-16	7.27e-11	4.66e-07
	Total			6.17e-05	0.396
2.5-year old Child	Inhalation	1	0.0281[a]	2.76e-8	2.36e-04
		2	0.0174[a]	1.71e-8	1.46e-04
	Ingestion vegetables	1	4.05e-10	6.32e-05	0.405
		2	6.93e-12	1.08e-06	6.93e-03
	Ingestion soil	1	2.73e-14	4.26e-09	2.73e-05
		2	1.55e-15	2.42e-10	1.55e-06
	Total	1		6.32e-5[b]	4.05e-1[b]
		2		1.10e-6[b]	7.08e-3[b]

[a]Values represent air concentrations.

[b]Total values were the sum of values in each period.