A PRELIMINARY DIOXIN INVENTORY FOR HONG KONG

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Introduction

"Dioxins", or more correctly polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are persistent organic pollutants (POPs) and include some of the most toxic pollutants known to humans. Due to their tendency to bioaccumulate throughout the trophic food chain, these compounds have become an important concern to regulatory organizations and are being addressed, together with ten other POPs, in the negotiations for a global treaty[1,2].

A number of countries have developed inventories of dioxin releases to atmosphere. Central to the compilation of an inventory is the estimation of emission factors, linking dioxin emissions with a unit of activity (for example, μg of PCDD/Fs (as I-TEQ) per tonne of waste incinerated, or μg of PCDD/Fs per kilometer traveled). These are typically obtained by sampling and analyzing PCDD/Fs from potential sources, and then averaging the measured emission factors across those particular activities to provide estimates of annual PCDD/F emissions on a national basis. In the absence of emission measurements within a particular activity, national PCDD/F emission inventories rely initially on emission factors derived elsewhere, in order to develop preliminary inventories which can then be refined and updated by conducting appropriate sampling programmes.

This paper summarizes the development of a preliminary dioxin inventory for Hong Kong.

Methods and Materials

In the absence of emission measurements for most activities, the preliminary inventory was established based on the UK's PCDD/F inventory of sources and where appropriate, emission factors derived for the it[3]. The estimate was calculated by the following basic equation:

Source Strength (dioxin emissions per year) = Emission Factor x Activity Rate

The PCDD/F emission pre year was calculated and presented in grams of toxic equivalent (I-TEQ) per year. The annual *Source Strength* is calculated by multiplying the release of PCDD/F (e.g. in μg I-TEQ) per unit of feed material processed or product produced (e.g. tonne or liter) – referred to as the *Emission Factor* – with the amount of feed material processed or product produced (tones or liter per year) – referred to as the *Activity Rate*.

A preliminary screening level assessment of potential industrial and non-industrial sources of PCDD/F emissions in Hong Kong was conducted. Activities which were identified as potential sources of PCDD/F emissions in Hong Kong were quantified. For the shortlisted processes and activities, the emission factors were selected from the UK study[3] or modified as appropriate, though preference was given to measured emissions as opposed to UK emission factors, where data for Hong Kong were available. A baseline of 1997 was selected as the most current year for which adequate activity data was available. Projected emissions for 2007 were estimated according to information on likely future activity patterns.

Results and Discussion

The estimated PCDD/F emissions for 1997 and 2007 are listed in Table 1.

Table 1 Estimated PCDD/F Emissions to Atmosphere from the HKSAR (1997 and 2007)

Sources	Activity (1997)	Inventory (1997, g I-TEQ)	Activity (2007)	Inventory (2007) g I-TEQ)
Industrial Sources:				
Coal combustion (power generation)	6.1 MT	0.4-2.0	5.6 MT	0.3-1.8
Landfill gas combustion				
Migrating gas	254,773 t CH_4	0..2-0.3	145,000 t CH_4	0.13-0.15
Flared gas	17,662 t CH_4	0.001	10,052 t CH_4	0.001
Non-ferrous metal	27,450	0.1-1.0	27,450	0.1-1.0
Cement manufacture[a]	1,514,838 t clinker	0.32	1,514,838 t clinker	0.32
MSW[e] combustion	116,508 t (old)	21-27	1,000,000 t (new)	0.5
Chemical waste combustion	10,198 t (CWTC)	0.004[b]	10,198 t (CWTC)	0.024[c]
Clinical waste Combustion[f]	3,650 t (old plant)	0.4-1.8	5,290 t (CWTC)	[c]
Sewage sludge combustion[f]	···	···	259,000 dry t	0.2
Asphalt mixing	84,050 t	0.004	84,050 t	0.004
Non-industrial Sources:				
Crematoria (human)	16,250 bodies	0.024	20,750 bodies	0.031
Animal Carcass Treatment Facilities	···	···	7,300 t[d]	0.015
Cars				
Leaded	2,049 M km	0.002-0.45	···	···

Unleaded (with catalytic converter)	2,237 M km	0.001-0.03	7,250 M km	0.003-0.09
Diesel	2,515 M km	0.002-0.03	2,515 M km	0.002-0.03
Light GVs (diesel)(e)	2,000 M km	0.001-0.02	2,400 M km	0.002-0.04
Heavy GVs (diesel)(e)	2,288 M km	0.06-0.09	2,557 M km	0.07-0.1
Buses (diesel)	612 M km	0.016-0.023	620 M km	0.016-0.023
Motorcycles	287 M km	0.0001-0.006	469 M km	0.0002-0.01
TOTAL		**23-33**		**2-4**

Notes:

(a) Assuming maximum operational conditions at 0.1 ng I-TEQ/m^3 limit, 7,680 h/year operation, 7,000 m^3/min flow rate and is not based on activity data.

(b) CWTC denotes Chemical Waste Treatment Centre which is the first integrated facilities in HK operational since 1991. It is equipped with a high temperature incineration facility with state-of-the-art dust removal and gas cleaning devices (with activated carbon injection). The emission limit of 0.1 ng I-TEQ/m^3 for PCDD/F has been adopted since its operation. According to its monitoring data, 4.3 mg I-TEQ of PCDD/F was released in 1997.

(c) Assuming maximum operational conditions at CWTC at 0.1 ng I-TEQ/m^3 limit, 8,000 h/year operation, 30,000 m3/h flow rate and includes both chemical and clinical waste incineration at the CWTC.

(d) Assuming average body weight of 70 kg, 7,300 t=100,000 bodies. For new plant, an emission factor of 0.15 μg I-TEQ/body, corresponding to an emission of 0.1 ng I-TEQ/m^3, is used.

(e) GV stands for goods vehicle; MSW denotes municipal solid waste.

(f) Fleasibility studies for developing MSW and sewage sludge combustion are still underway and the HKSAR Government has not yet decided on the right waste management option. The figures estimated for 2007 above have been based on the assumption their adoption and an operational emission limit of 0.1 ng I-TEQ/m^3 for PCDD/Fs.

In compiling the inventory, we have discounted the following processes and activities, we have made the following assumptions regarding several proposed treatment facilities.

Municipal waste combustion (MSW). Studies are underway to explore the feasibility for adopting thermal incineration as bulk volume reduction and energy recovery facilities for MSW. In estimating the dioxin inventory, we have assumed that a total projected incineration capacity of 1 million tonnes per annum will have been installed by 2007. The proposed new facilities will be operating to an emission limit of 0.1 ng I-TEQ/m^3. Assuming a nominal gas generation rate of 5,140 m^3/tonne, this results in an emission factor of 0.514 μg I-TEQ/tonne, rounded to 0.5 μg I-TEQ/tonne.

Sewage sludge incineration. The UK emission factors of 9-77 μg I-TEQ/tonne (dry) reflect the presence of both new and old plants, the former operating to an emission limit of 0.8 ng I-TEQ/m^3. However, these plants can operate to lower limits, and currently are typically guaranteed by equipment suppliers to operate within the 0.1 ng I-TEQ/m3 emission limit applied to other types of waste combustors. Therefore in developing a PCDD/F inventory, we have applied an emission factor of 1 μg I-TEQ/tonne dry solids to reflect PCDD/F emissions at 0.1 ng I-TEQ/m^3.

Chemical waste incineration. Since measured PCDD/F emissions are available for the Chemical Waste Treatment Centre (CWTC), these were used directly to estimate annual emissions. For 1997, the CWTC monitoring data reports that 4.3 mg I-TEQ of PCDD/F was released, equal to 0.004 g I-TEQ per annum.

Clinical waste incineration. The Hong Kong SAR Government is now considering the feasibility of co-treating clinical waste (an extra 7 tonnes per day on top of the 60 tonnes chemical waste per day) at the CWTC high temperature incineration system. For the sake of this study, we have assumed the same operational PCDD/F emission limit of 0.1 ng I-TEQ/m^3, a gas flow of 30,000 m^3/h from the combustion of clinical waste and an operating year of 8,000 h. A mass emission of 0.02 g I-TEQ per year was calculated. This emission was added to the estimated emission of 0.004 g I-TEQ per year resulting from the combustion of chemical waste, giving a combined emission of 0.024 g I-TEQ per year.

Crematoria. The PCDD/F emission limit for crematoria in Hong Kong is set a 1 ng I-TEQ/m^3. The emission factor for crematoria was developed by assuming a gas generation rate of 1,500 Nm^3 per human body[4]. An emission factor of 1.5 µg I-TEQ per body is calculated.

Animal carcass treatment facilities. It is assumed that the animal carcass treatment facilities, based on the design of a thermal combustor, will operate to a PCDD/F emission limit of 0.1 ng I-TEQ/m3. If it is further assumed that the same gas generation rate for humans also applies to animal carcasses, an emission factor of 0.15 µg I-TEQ/body is estimated.

Cement manufacture. We have estimated an annual mass emission from data provided by the cement company (see note (a) attached to Table 1), in preference to a mass emission calculated from UK emission factors.

It should be noted that the use of 1997 data does not necessarily influence the predictions for 2007, since different approaches were used for some sources.

Based on stack measurements between 1995 and 1997, Alcock *et al.*[5] estimated that the emission inventory for 1997 had decreased from 560-1100 g I-TEQ/a[3] to 220-660 g I-TEQ/a, with MSW incinerators contributing between 30-60% of total PCDD/F (I-TEQ) emissions as opposed to 53-82% in 1994/95. According to the data of the present study in Table 1, MSW incineration dominated the PCDD/F inventory for Hong Kong in 1997, but the total inventory, i.e. the summation of all sources listed in the table (approximately 30 g I-TEQ per year in 1997), is far less than comparable inventories elsewhere, particularly for the UK. This is due to a combination of a lower level of population in Hong Kong (6.5 million as opposed to 60 million in the UK) and

lower levels of industrial activity that have been traditionally associated with historical national inventories (e.g. MSW and clinical waste incinerators, and secondary metal refining) and the absence of sources such as sinter plants. Currently operating thermal waste treatment processes in Hong Kong are of relatively small scale, and the sole chemical waste treatment incinerator (the CWTC) introduced to Hong Kong in recent years has adopted technology and a PCDD/F emission limit (0.1 ng I-TEQ/m^3) that is presently regarded as constituting best practice in terms of PCDD/F emissions. The latter will also apply to the subsequent proposed MSW, sewage sludge and animal carcass treatment facilities should there be decisions to proceed with these options in future. Therefore, the historical legacy of PCDD/F emissions due to the operation of thermal waste treatment processes has to a large extent been avoided.

The net reduction in PCDD/F emissions between the 1997 estimates and the projections for 2007, is primarily due to the closure of old MSW incineration plants. Despite the significant increase in the tonnage of MSW, sewage sludge and animal carcasses incinerated by 2007 as compared to 1997, the proposal to operate these incinerators at a PCDD/F emission limit of 0.1 ng I-TEQ/m^3 will still result in a net decrease in PCDD/F emissions relative to 1997. However, this would be a very preliminary estimate as there is incomplete activity data or information available for all the major sources in 1999.

In the present study, we have omitted emissions from accidental fires, natural fires, etc. Emission factors for these events are difficult to estimate with any degree of certainty. A detailed discussion is contained in HMIP[6], in which an emission factor range of 1-28 µg I-TEQ per tonne of material consumed is derived for open natural fires. Bonfires also have the potential to release PCDD/Fs to atmosphere[7]. The same difficulty in estimating a PCDD/F emission factor applies in the case of accidental fires[6]. The potential for PCDD/F formation will depend on the combustion conditions, and on the presence or absence of chlorinated materials such as polyvinyl chloride (PVC). Contrasting PCDD/F emission estimates have been proposed, from 3 mg I-TEQ from a fire involving 200 tonnes of PVC and 500 tonnes of carpeting, to 13 kg of total PCDD/Fs from a fire involving 600 tonnes of rigid PVC[6].

This study is the first of its kind being conducted for Hong Kong. The preliminary inventory will be subject to revision based on the updated data obtainable from emissions monitoring and activities measurement. Further work is thus required to quantify PCDD/F emissions from the proposed facilities if being put into actual operation in future.

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