An Assessment of Dioxin Emissions in Hong Kong
Summary of Findings

In November 1999 Environmental Resources Management (ERM) was commissioned by the Environmental Protection Department, Government of the Hong Kong Special Administrative Region (HKSAR) to undertake a study entitled *An Assessment of Dioxin Emissions in Hong Kong.* The tasks undertaken in the study were as follows:

1. To review ambient air monitoring data for dioxins (PCDD/Fs) in Hong Kong, and advise on the likely significant sources of dioxin.

2. To review existing emissions data and health assessment studies, and assess whether the local community is being exposed to a dangerous level of dioxins emitted by the existing waste management facilities.

3. To advise on the dioxin monitoring requirements including ambient monitoring and the monitoring of other dioxin sources considered to be significant.

4. To review and advise on the short and long term impacts of dioxin emissions, including the cumulative effect of existing and planned incineration facilities.

5. To advise on the control limit on dioxin emissions from the new incineration facilities in the light of international practice and of (4) above.

6. With respect to the Chemical Waste Treatment Centre (CWTC), to audit the dioxin emission control mechanism, taking into account the future co-combustion of clinical waste.

7. To advise on the limit of exposure of the public to dioxin emissions from all significant identified sources, and on the risk, contingency and emergency response measures in the event of any mal-operation leading to significant release of dioxins.

This paper summarises the outcomes of the above tasks.

TASK 1: LIKELY SIGNIFICANT SOURCES AND REVIEW OF AMBIENT PCDD/F DATA

Likely Significant Sources

The Consultants have compiled a preliminary PCDD/F emission inventory for Hong Kong, based on their understanding of the principal industrial and non-industrial sources and their levels of activity (Table 1). For a baseline year of 1997, total PCDD/F emissions to the atmosphere were estimated to be 23 to 33 g I-TEQ (excluding adventitious sources such as fires), of which an average of 85% was attributable to the combustion of municipal solid wastes in old incineration systems.

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)	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
■ combustion gas	NA	NA	NA	NA
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 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	3,650 t (old plant)	0.4-1.8	5,290 t (CWTC)	(c)
Sewage sludge Combustion	-		259,000 dry t 0.2	0.2
Asphalt mixing	84,050 t	0.004	84,050 t	0.004
Non-Industrial Sources				
Crematoria				
■ humans	16,250 bodies	0.024	20,750 bodies	0.031
■ animals	-		7,300 t (d)	0.015
Cars				
■ leaded	2,049 M km	0.002-0.45	-	-
■ unleaded (with cat)	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
■ LPG	-	-	2,600 M km	-
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 0.1ng I-TEQ/m^3 limit[1], 7,680hrs/year operation, 7,000m^3/min. flow rate and is not based on activity data.

(b) According to CWTC monitoring data, 4.3 mg I-TEQ of PCDD/F was released in 1997.

(c) Assuming maximum operational conditions at CWTC at 0.1ng I-TEQ/m^3 limit, 8,000hrs/year operation, 30,000m^3/hr 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 0.15µg I-TEQ $body^{-1}$, corresponding to an emission of 0.1ng I-TEQ m^{-3}, is used.

(e) GV stands for goods vehicles.

In order to estimate future emissions in 2007, the Consultants have conservatively assumed that 1 million tonnes of MSW incineration capacity will have been installed, together with sewage sludge and animal carcass incinerators, and that clinical waste will be combusted in the CWTC. All these

[1] Concentrations of PCDD/Fs are expressed as picogrammes (pg) or nanogrammes (ng) of the chemicals (generally expressed as I-TEQ) per gramme (g) of the medium or per cubic metre (m3) if a gaseous medium. 1 pg is equal to 1/1,000,000,000,000 of a gramme (or one million millionth of a gramme) while 1 ng is equal to 1/1,000,000,000 of a gramme (or one part in one thousand millionth of a gramme).

proposed facilities would operate to a state-of-the-art PCDD/F emission limit of 0.1 ng I-TEQ m^{-3}. The net outcome will be a reduction in PCDD/F emissions to 2 to 4 g I-TEQ per annum, principally resulting from the closure of the old municipal solid waste incineration facilities.

The current and future PCDD/F inventory for Hong Kong is lower than that for other national inventories per head of population, owing to a generally low level of combustion and industrial activity, but more significantly to the fact that Hong Kong has adopted a PCDD/F emission limit of 0.1 ng I-TEQ m^{-3} for all existing and proposed waste incineration facilities, in line with the best practice elsewhere.

Review of Ambient Air Monitoring Data

The Consultants reviewed the PCDD/F ambient air quality monitoring data collected at two urban sites, Central/Western and Tsuen Wan. The data for 1997-1999 indicated a strong seasonal trend, with ambient dioxin levels higher during winter months (median concentrations 0.132 pg I-TEQ m^{-3} in winter versus 0.047 pg I-TEQ m^{-3} in summer) when winds originated from the industrialised north. The median PCDD/F concentration at the monitoring sites was within the range of concentrations measured at major urban sites worldwide. Ambient air quality monitoring conducted by Enviropace[1] in the vicinity of the CWTC elicited concentrations that were lower than those measured close to major sources in Germany (<0.002-0.17 pg I-TEQ m^{-3} versus 0.35-1.6 pg I-TEQ m^{-3} in Germany) and were typical of the reported concentrations at Tsuen Wan and Central/Western. These data indicate that ambient PCDD/F levels in Hong Kong are similar to those in other urban locations. In the vicinity of the CWTC, PCDD/F levels are indistinguishable from those at other urban locations in Hong Kong, and lower than concentrations measured in the vicinity of major PCDD/F sources in Germany. This implies that the CWTC emissions do not markedly impact air quality in the local area.

TASK 2: PCDD/F STACK EMISSIONS AND HEALTH IMPACT OF EXISTING FACILITIES

Modelling of CWTC stack emissions indicated that the facility was likely to contribute 0.1 to 0.4% of existing ambient air concentrations. Current sampling and analytical methods are unable to achieve this level of discrimination, and the ambient measurements in the vicinity of the facility confirm the lack of a significant impact on local air quality.

The Consultants have conservatively estimated the dietary intake of PCDD/Fs, the dominant intake pathway into humans, as 105 pg I-TEQ day^{-1} (equivalent to 1.5 pg I-TEQ kg^{-1} (bw) day^{-1})[2]. This preliminary estimate lies within the range of PCDD/F intakes measured in other urbanised areas. However, since the majority of food items consumed in Hong Kong are imported, PCDD/F emissions from waste treatment facilities in Hong Kong have only a marginal influence on this intake pathway.

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[1] Enviropace Limited is Government's contractor to design, build and operate the Chemical Waste Treatment Centre (CWTC).

[2] This is equivalent to 1.5 pg I-TEQ per kilogram body weight per day.

TASK 3: PCDD/F MONITORING REQUIREMENTS

Monitoring requirements at individual sources and in ambient environment were reviewed. With respect to the former, the types of source and monitoring frequency is summarised in Table 2.

Table 2 Proposed Monitoring Frequency of Various PCDD/F Sources

Sources	Monitoring Frequency
MSW incinerator	Monthly
Sewage sludge incinerator	Monthly in year 1, followed by one sample every 2 months
Animal carcass incinerator	Monthly in year 1, followed by one sample every 3 months
Cement kiln	One sample every two months
CWTC	Continue with monthly samples

The Consultants recommend that monitoring at source be supplemented with ambient monitoring of soil/dust and grass in the vicinity of the existing and proposed waste treatment facilities. It is suggested that on the basis of the dispersion modelling conducted for each of the proposed facilities, three sampling locations be selected, two being in the downwind direction and one in an upwind direction to act as a control. At each of the sampling locations it is suggested that soil/dust and grass be analysed for PCDD/Fs on a biannual basis.

In addition, the Consultants recommend the institution of a food surveillance programme to record PCDD/F levels in both indigenous and imported food items. The food products should include fish, milk and dairy products, meats and vegetable products. Initially, a pilot study should be conducted to establish the scope and frequency of the ongoing surveillance programme.

If the analytical scope of the pilot programme is extended to include coplanar PCBs, this data will also allow a calculation of the intake of PCDD/Fs and dioxin-like PCBs for comparison with the WHO recommended tolerable daily intake of 1 to 4 pg WHO-TEQ kg^{-1} (bw) day^{-1}. The contribution of coplanar PCBs to the total TEQ of the food samples will provide useful information for the overall management of PCDD/F intake via the diet, and will also indicate whether these chemicals should be included in the source sampling programme.

TASK 4: SHORT AND LONG TERM IMPACTS OF DIOXIN EMISSIONS

The accumulative nature of PCDD/Fs and low levels of emissions indicated to the Consultants that the relevant impacts to be considered were chronic, long term impacts rather than acute, short term impacts. The PCDD/F emissions inventory for Hong Kong indicated a net reduction in local PCDD/F emissions between 1997 and 2007. Management of each facility should focus on achieving and maintaining an acceptable local ambient air ground level concentration of PCDD/Fs following their release from the stack. With the dispersion modelling predicting each site contributing less than 0.001 pg I-TEQ m^{-3} to ambient air levels, the Consultants concluded that the cumulative effect of the planned facilities was acceptable in terms of the likely cumulative health impact.

TASK 5: CONTROL LIMIT ON DIOXIN EMISSIONS FROM THE NEW FACILITIES

The Consultants recommend that a PCDD/F emission limit of 0.1 ng I-TEQ m^{-3} be placed on the proposed facilities for the incineration of MSW, sewage sludge, and animal carcasses, as representing best practice in the industry. This emission limit should also apply to the management of clinical waste if this material is incinerated in a dedicated stand-alone facility rather than in the CWTC. A PCDD/F emission limit of 0.1 ng I-TEQ m^{-3}, in conjunction with an appropriate stack height, will result in maximum ambient air ground level concentrations being less than 0.001 pg I-TEQ m^{-3}, which in the context of the background exposure is not regarded as being likely to impact adversely on public health.

TASK 6: AUDIT OF CWTC DIOXIN EMISSION CONTROL SYSTEM

The Consultants have taken a broad view of the factors that influence PCDD/F emission, and therefore have audited a number of control activities and design features upstream of the pollution abatement system. The key conclusions with respect to the proposed co-incineration of clinical waste are as follows.

Feedstock Control: The Consultants conclude that the waste feeding systems, with preference for a ram feeding system, proposed for the introduction of clinical waste to the kiln are appropriate for maintaining even and stable combustion conditions within the kiln.

Maximisation of Combustion Efficiency: The CWTC is operating at temperatures that are appropriate for the combustion of clinical waste and will provide the combustion gases with sufficient residence time and turbulence to ensure good mixing with air and effective burnout of the waste.

Management of Waste Heat Boiler Conditions: The CWTC boiler is designed for an exit temperature of 380℃, towards the high end of the PCDD/F formation window. Regular cleaning of the boiler tubes will also minimise the potential for build-up of flyash.

Management of Pollution Control Devices: The configuration and management of the pollution control device on the CWTC facility is appropriate for the co-combustion of clinical waste, as was demonstrated in a trial burn when two PCDD/F emission concentrations of 0.016 and 0.027 ng I-TEQ m^{-3} were measured, well within the specified limit of 0.1 ng I-TEQ m^{-3}. It should be noted that the activated carbon injection system was not operational during the trial burn. There is sufficient redundancy designed into the pollution control system to ensure that the unit operates in the event of a malfunction.

At the CWTC, the carbon injection system has recently been upgraded to consist of two parallel and equivalent systems, each is connected to a separate power supply and operating continuously but independently of each other. Failure or malfunction of one line results in the gases being diverted into the continuously operating back-up system without time delay, thereby providing uninterrupted cleaning of the gas stream.

Control and Monitoring of System Variables: The CWTC monitors and records all the necessary kiln, secondary combustion chamber and stack discharge parameters for effective control of the combustion conditions.

Emergency and Failsafe Systems: The CWTC has a comprehensive emergency response system to enable the facility to engage in a controlled shutdown sequence. All key malfunction options are linked through interlocks to termination of the waste feed, and diversion to emergency power and water supplies.

The Consultants conclude that the design and management of the CWTC is suitable for the co-incineration of clinical waste with chemical waste in a safe environment, and that the specified PCDD/F emission limit of 0.1 ng I-TEQ m^{-3} can be achieved.

TASK 7: ADVICE ON THE LIMIT OF EXPOSURE TO DIOXIN EMISSIONS

Based on the judgement that cumulatively in a year no one facility should contribute more than 1% to the background ambient air concentration of PCDD/Fs on an annualised basis, the Consultants suggest an emission concentration of 2 ng I-TEQ m^{-3} as a trigger for reviewing to appropriate levels of detail the facility's operational and control measures, with the intention of bringing the following month's emission measurement back to within the stated limit of 0.1 ng I-TEQ m^{-3}.

In concert with in-stack monitoring, the Consultants also recommend that the HKSAR Government institutes a food surveillance programme, commencing with a scoping exercise in the form of a pilot study. Milk is regarded in some countries as a particularly sensitive indicator of PCDD/F uptake, and dairy farms downwind of municipal solid waste incinerators are often placed on the surveillance programme. This scenario is unlikely to present itself in Hong Kong, but nevertheless the pilot study may identify alternative but equally viable biological matrices as PCDD/F pollution indicators.

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