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## Destruction of DDT wastes in two preheater/precalciner cement kilns in China



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### HIGHLIGHTS

- DDT waste can be effectively destroyed by feeding to the flue gas chamber in dry process cement kiln.
- The emissions of PCDD/PCDFs and HCB in the flue gas varied in the range of 0.0019–0.0171 ng I-TEQ/Nm<sup>3</sup> and 0.0064–0.0404 µg/Nm<sup>3</sup>, respectively.
- The emission factor for PCDD/PCDF and HCB varied from 0.0137 to 0.0281 µg/ton and from 17.32 to 109.34 µg/ton of clinker, respectively.
- The uncertainty of a buildup of trace not-destroyed compounds for further study is identified.

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### ABSTRACT

The destruction of DDT formulations and DDT contaminated soil was conducted by feeding wastes into the flue gas chamber at the kiln inlet of two different preheater/precalciner cement kilns in China. The concentration of DDT, PCDD/PCDFs and HCB were measured in the flue gas of the main stack, in the solid material under baseline conditions and when feeding DDT-wastes. The destruction efficiency and the destruction and removal efficiency for DDT were in the range of 99.9335%–99.9998% and 99.9984%–99.9999%, respectively. The emissions of PCDD/PCDFs and HCB in the flue gas varied in the range of 0.0019–0.0171 ng I-TEQ/Nm<sup>3</sup> and 0.0064–0.0404 µg/Nm<sup>3</sup>, respectively. The emission factor for PCDD/PCDF and HCB varied from 0.0137 to 0.0281 µg/ton and from 17.32 to 109.34 µg/ton of clinker, respectively. The concentration of PCDD/PCDFs and HCB in solid samples decreased as follows: cement kiln dust, 4.1–5 ng I-TEQ/kg and 0.70–0.71 µg/kg, respectively; >raw meal, 0.82–0.97 ng I-TEQ/kg and 0.18 µg/kg, respectively; >cement clinker, 0.09–0.22 ng I-TEQ/kg and 0.14–0.18 µg/kg, respectively. This study indicates that the feeding of DDT and POPs-wastes to the lower temperature part of a cement kiln system possibly to create a buildup of trace not-destroyed compounds in the system and might cause emissions; the technical feasibility and the environmental acceptability of this practice need to be investigated thoroughly.

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### 1. Introduction

The Stockholm Convention on persistent organic pollutants (POPs) states in Article 6 that POPs and POPs-wastes should be destroyed or disposed of in a way that the POPs content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of POPs (UNEP, 2001). The Basel Convention technical guidelines for Environmentally Sound Management of POPs-wastes has described 12 technologies, which might be qualified, including high temperature incinerators, cement kilns, alkali metal reduction, gas-phase chemical reduction, supercritical water oxidation, etc. (UNEP, 2004, 2007). The techniques can broadly be divided into two main groups, thermal and chemical

treatments (non-combustion; a comparison of the technologies is however lacking making it difficult to compare the performance and feasibility) (Karstensen et al., 2010).

Cement kilns possess many advantages that make them suited for organic hazardous waste treatment, including high temperatures, long residence time, good turbulence and mixing conditions and surplus oxygen. The co-processing of wastes as alternative fuel and raw materials is widely adopted in many developed and developing countries (UNEP, 2006; Kulkarni et al., 2008; Abad et al., 2004; Conesa et al., 2006, 2008, 2011; Stobiecki et al., 2003; Van Loo, 2008; Karstensen et al., 2006, 2010; Zabaniotou and Theofilou, 2008; Schuhmacher et al., 2002; Zemba et al., 2011; Ames et al., 2012; Sikkema et al., 2011); furthermore, cement kiln is playing more and more important role for waste disposal in China (Kao et al., 2007; Li et al., 2009; Yang et al., 2012; Li et al., 2012a,b,c,d; Yan et al., 2009; Huang et al., 2012; Zhou et al., 2008).

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Since the 1970s, numerous studies and surveys have been carried out by many developed and developing countries to evaluate the performance of cement kiln co-processing and destruction of hazardous wastes and its possible impact on cement quality and environment. The results of these studies normally demonstrate that there are no or small differences in the emission or the product quality when waste materials are disposed by modern cement kiln system (Abad et al., 2004; Conesa et al., 2006, 2008, 2011; Karstensen et al., 2006, 2010; Karstensen, 2008); the flue gas concentration of PCDD/PCDF is normally below the value of 0.1 ng I-TEQ/Nm<sup>3</sup> (Van Loo, 2008; Karstensen, 2008).

There are several potential feed points for hazardous waste to the cement kiln system, including the main burner at the rotary kiln outlet, the flue gas chamber at the rotary kiln inlet and the precalciner, where the flue gas temperature reach 2000 °C, 1050 °C and 900 °C, respectively. The residence time of flue gas at temperatures above 800 °C is in order of 13 s for the main burner, 3–4 s in the flue gas chamber and 1–3 s in the precalciner (UNEP, 2006; Li et al., 2012b). The main burner is usually fed with homogeneous liquids or fine powders with smaller particle sizes, not lump solid wastes, which is normally fed into flue gas chamber at the kiln inlet or directly into the precalciner. The oxygen content in main burner zone, flue gas chamber and precalciner is normally 2%–10%, 1%–2% and <3%, respectively (UNEP, 2006). The sewage sludge, obsolete pesticides and even PCB oil were thoroughly destroyed when fed through the main burner (Karstensen et al., 2006, 2010; Abad et al., 2004). A limited studies and test burns have been carried out with feeding obsolete pesticide, sewage sludge, contaminated soil and municipal solid waste to the flue gas chamber at the kiln inlet or in the precalciner, usually because the temperatures and the residence time are considered to be too low. These feeding points are however widely used in China and were the primary interest of this study.

China is facing increasing pressure to come up with sound hazardous waste management and disposal options; co-processing and destruction in cement kilns can be one option. The use of cement kilns for hazardous waste disposal has been practiced for a limited time in China, and there is an urgent need for validating the practice. In this study, DDT formulations and DDT contaminated soil were fed to the flue gas chamber at kiln inlet in two different dry process preheating/precalcination kiln systems. The concentration of DDT, PCDD/PCDFs and HCB were measured in the DDT feedings, raw meal, clinker, cement kiln dust and flue gas to calculate the destruction efficiency (DE), and the destruction and removal efficiency (DRE) and emission factors of PCDD/PCDFs and HCB were calculated.

## 2. Materials and methods

### 2.1. Obsolete DDT powder

The obsolete DDT powder destroyed in this study came from one regional Centers for Disease Control (CDC) in the Hunan Province of China. As DDT became banned internationally, the CDC started in 1985 to store DDT in specialized warehouse. The light-yellow colour DDT powder was contained in 2 kg plastic bottles.

The total concentration of DDT was measured to be 10.63%, with 0.07% (pp'-DDE), 0.55% (pp'-DDD), 3.86% (op'-DDT) and 6.16% (pp'-DDT). The remaining composition were water dissolvable agent and dispersant.

### 2.2. DDT contaminated soil

The DDT contaminated soil was excavated from a pesticide production plant. From 1975 to 2009, this plant produced pure DDT and water dissolvable powder for domestic use and export. Since the product was in the form of fine powders, the workplace and surrounding area and downstream area were sampled and tested for DDT concentration. High concentrations were found in the surrounding area. The contaminated soil were temporarily stored in 2 concrete liner ponds with a dimension of 10 m × 10 m × 5 m, with a total weight estimated to be 600 tons. The soil was filled in big bags, 1 ton/bag, and transported to the cement plant for destruction. The DDT concentration of contaminated soil varied within 1352–3394 mg/kg.

### 2.3. Cement plants and test conditions

The schematic diagram and the major test parameters for DDT powder destruction in kiln A and the contaminated soil in kiln B are shown in Table 1 and Fig. 1.

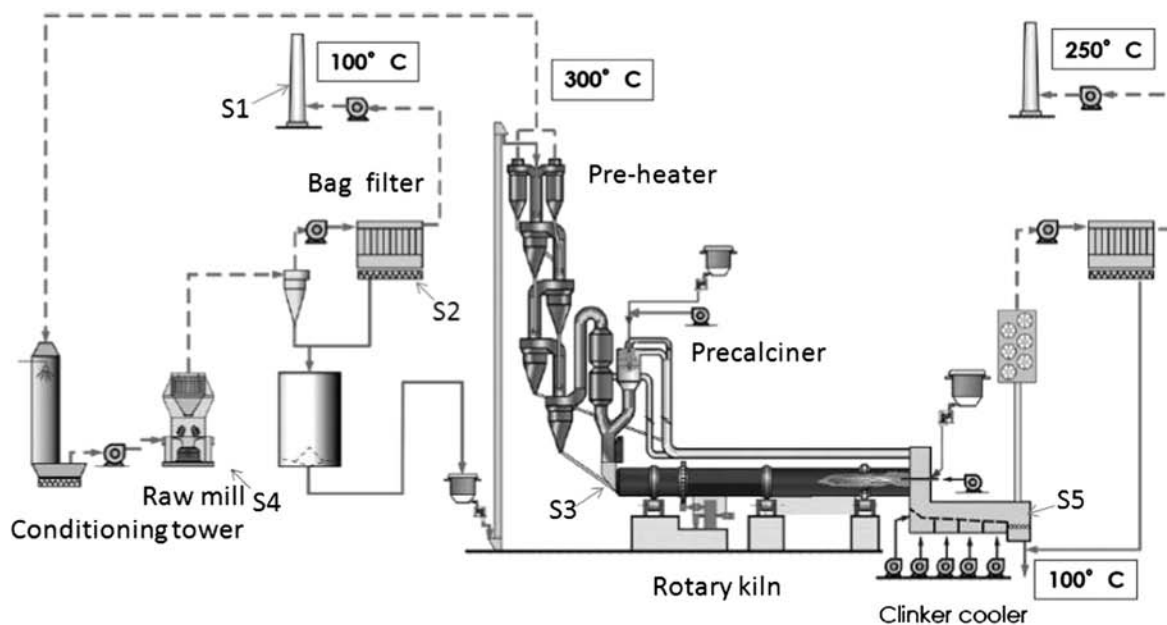
Both A and B kiln systems have similar technical outline, and the sampling points are indicated in the figure. Flue gas was sampled at the S1 location in the main stack, cement kiln dust (CKD) was sampled at the hopper of the bag filter in plant A and in the ESP of plant B (S2), raw meal (RM) was sampled at the raw meal homogenizing silo (S4), the DDT powder and contaminated soil was sampled at the S3 and cement clinker (CK) was sampled from the conveyer belt after the grate cooler at S5. All the measurements were conducted when the respective raw mills were operating in function.

**Table 1**  
Cement plants and test conditions.

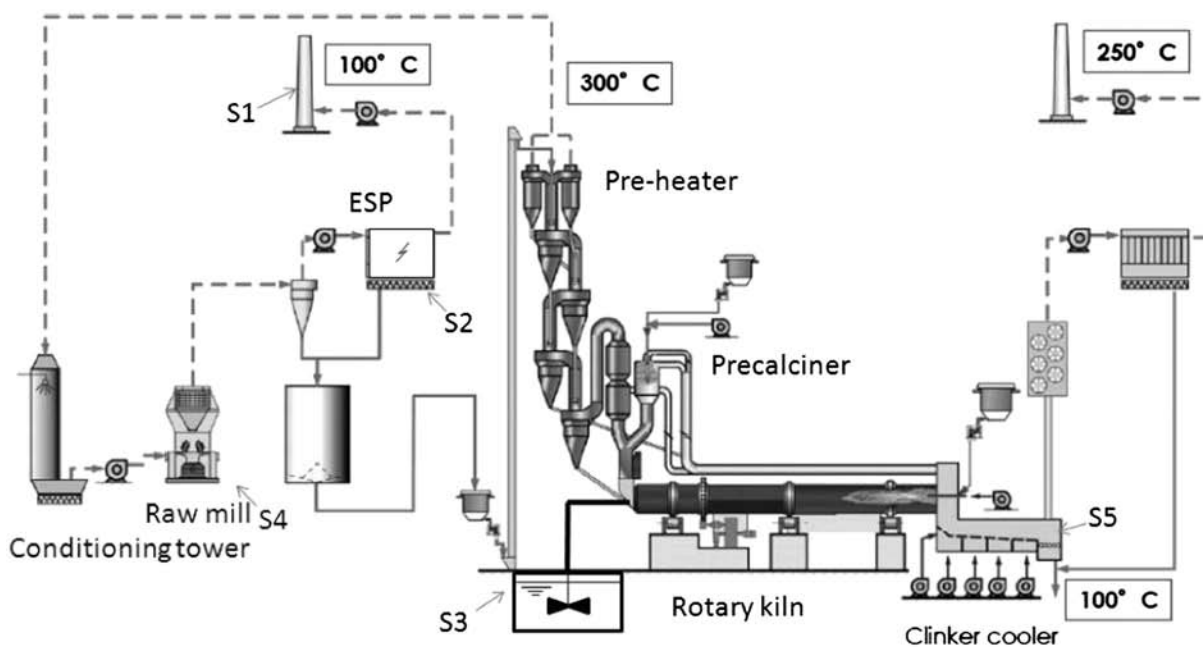
	Test with DDT powder Plant A (29 and 30 December 2010)	Test with DDT contaminated soil Plant B (25 and 26 November 2011)
Name of cement plant	Huaxin Wuxue Cement, Hubei Province	Hebei Yanxin Cement, Hebei Province
Air pollution control equipment (flue gas inlet temperature)	Bag house filter (134 °C)	Electrostatic precipitator (120 °C)
Raw meal consumption (t/h)	364	118
Coal consumption (t/h)	30	11
Clinker production (t/h)	228	74
Cement kiln dust production (t/h)	22	7
Exit gas volume (Nm <sup>3</sup> /h)	471,000	200,000
Feed rate of DDT waste (t/h)		
Baseline test	0	0
Feed rate of DDT waste (t/h)	1.0	0.83
Average DDT concentration	A-Test1                      10.63% DDT powder	B-Test1                      1350 mg/kg
	A-Test2	B-Test2                      1470 mg/kg
	A-Test3	B-Test3                      3390 mg/kg

1. Raw meal (RM) and flue were sampled under the A-Test0; flue was sampled under the A-Test1, A-Test2 and A-Test3; the clinker (CK) and cement kiln dust (CKD) was respectively sampled during the process of A-Test1, A-Test2 and A-Test3, then blending into one sample as A-Test1,2,3-CK and A-Test1,2,3-CKD. The PCDD/PCDFs and DDT were analyzed for all samples under the A-Test.

2. RM, CKD, CK and flue were sampled under the B-Test0; Flue, CK and DCS were sampled under the B-Test1, B-Test2 and B-Test3, respectively; the cement kiln dust (CKD) was sampled during the process of B-Test1, B-Test2 and B-Test3, then blending into one sample as B-Test1,2,3-CKD. The PCDD/PCDFs, DDT and HCB were analysed for all samples under the B-Test.



a) Dry process cement kiln with preheater and precalciner in Hubei Province(Plant A).



b) Dry process cement kiln with preheater and precalciner in Hebei Province(Plant B).

Fig. 1. (a,b) Dry process cement kiln with preheater and precalciner (sampling points indicated).

#### 2.4. Sampling and analytical methods

Flue gas samples were collected isokinetically from the main stack following the Chinese National Standard for PCDD/PCDF Emission Analysis of Ambient Air and Waste Gas (HJ77.2) (MEP China, 2008a, b). Samples of raw meal, clinker and cement kiln dust were collected every 30 min and analysed according to Chinese National standard for PCDD/PCDF Analysis of Solid Waste Samples (HJ77.3) (MEP China, 2008a,b).

The sampling of DDT and HCB in flue gas and solid samples were performed according to China's national standard of Sampling method of Determination of particulate and gaseous pollutant for stationary source (GB/T16157-1996) (MEP China, 1996) and HJ 77.2-2008 and GBZ/T 160.77-2004 (MEP China, 2004) of test method for hazardous substance of organic chlorinated pesticide in ambient air in work place. The analytical method for DDT and HCB in flue gas and the solid sample were performed according to the Chinese National Standard of GB/T14550-2003 (MEP China, 2003).

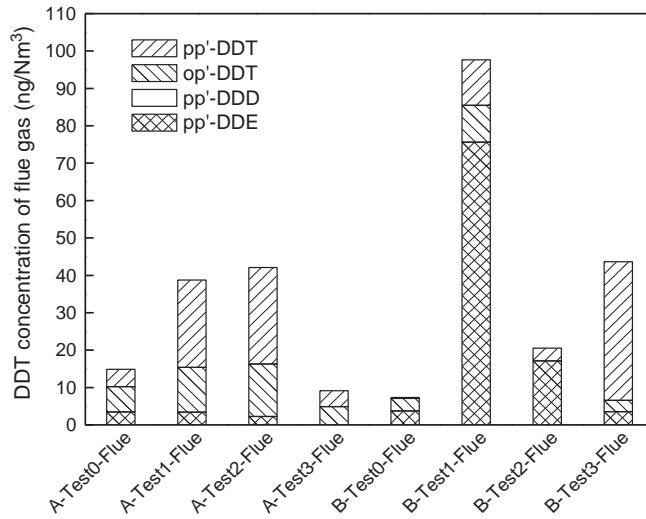


Fig. 2. DDT concentrations in the flue gas from cement kilns A and B.

### 3. Results and discussion

#### 3.1. DDT emissions in flue gas and clinker

Fig. 2 shows the DDT concentration in flue gas when feeding the DDT powder in kiln A and contaminated soil in kiln B. For the test burn with DDT powder, the DDT concentrations were 14.8 ng/Nm<sup>3</sup> in the baseline blank test (no DDT-feeding), increasing to 38.8 ng/Nm<sup>3</sup> (A-Test 1) and 42.1 ng/Nm<sup>3</sup> (A-Test 2), then declining to 9.2 ng/Nm<sup>3</sup> (A-Test 3), done when feeding 1 ton DDT powder/h.

For the test burn of contaminated soil (DCS), the DDT concentrations were 7.4 ng/Nm<sup>3</sup> in the baseline blank test (no DDT-feeding), increasing to 97.6 ng/Nm<sup>3</sup> (B-Test 1), declining to 20.6 ng/Nm<sup>3</sup> (B-Test 2), then increasing to 43.7 ng/Nm<sup>3</sup> (B-Test 3), done when feeding 0.833 ton DDT-contaminated soil/h.

DDT was identified and quantified in the flue gas under baseline conditions, i.e., when not feeding DDT in both plants. It can also be observed that the concentration of DDT in flue gas increases when both kilns are feeding DDT powder and contaminated soil; also been observed by others (Yang et al., 2012; Li et al., 2012b). It may indicate that DDT is not thoroughly destroyed or that a circulation phenomenon has been established. In another test burn with DDT (Li et al., 2012a), DDT was not detected during baseline but was detected when the feeding load of DDT was over 1 ton/h, with a flue gas concentration of 49–73 ng/Nm<sup>3</sup>.

The reason why we could identify DDT under baseline conditions is most probably because both kiln systems had been disposing DDT and other POPs-wastes prior to our tests and constituting a “memory” effect; however, this needs further investigation.

Fig. 3 shows the DDT concentration in solid matters when feeding the DDT powder in kiln A and contaminated soil in kiln B. DDT could not be detected in raw meal from plant A, but the concentration was 0.0682 ng/g in cement clinker and 7.78 ng/g in cement kiln dust during the test burn with DDT powder.

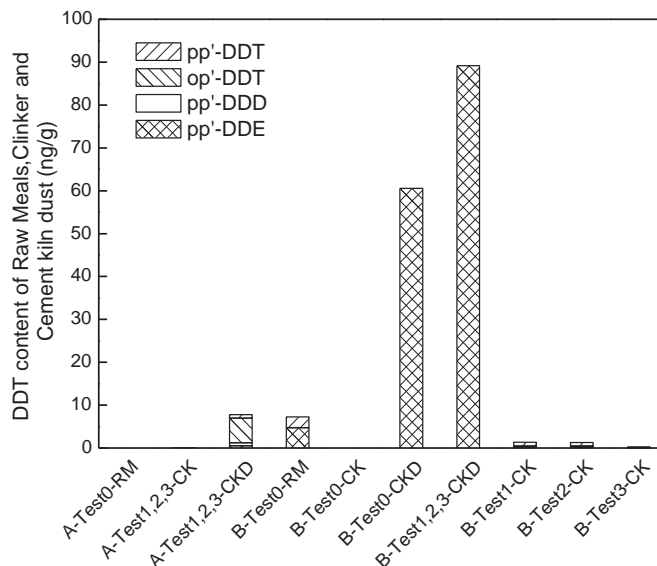


Fig. 3. DDT content of in raw meal, clinker and cement kiln dust.

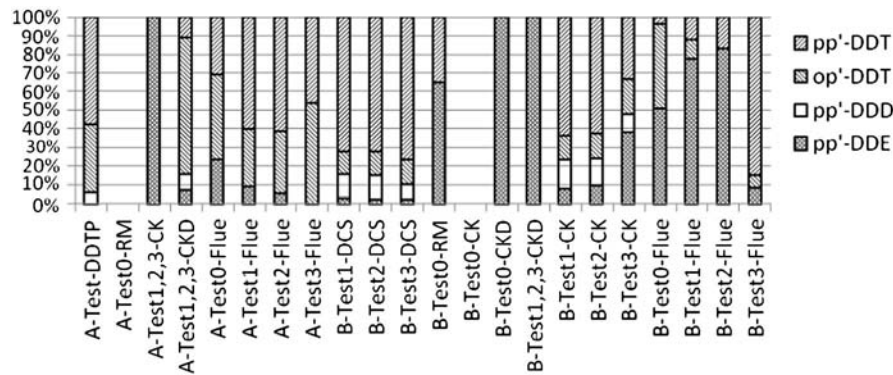


Fig. 4. DDT isomeric group profile.

DDT (7.27 ng/g) was detected in raw meal from plant B; samples of cement clinker showed from 0 to 1.32 ng/g (B-Test1-CK), 1.31 ng/g (B-Test2-CK) and 0.21 ng/g (B-Test3-CK); samples of cement kiln dust showed 60.56 ng/g in the baseline condition and 89.18 ng/g (B-Test1,2,3-CKD) during the test burn of contaminated soil. In the test burn of DDT (Li et al., 2012a), there was no DDT detected in cement kiln dust when not feeding DDT, the DDT was detected when the feeding load of DDT was over 1 ton/h and DDT concentration in CKD rose up in the range of 9–14 ng/g with the feeding load increasing.

The DDT content of cement kiln dust was significantly higher compared to the other solid samples in both plants, which can be expected (Karstensen, 2008). Since both kilns had been disposing large quantities of POPs-wastes prior to our test, this was causing accumulation and buildup of POPs in the system. The cement kiln dust is trapped in the air pollution control system and recycled back to the process, i.e., mixed with fresh raw meal in the raw meal silo and fed back to the kiln. This circulation pattern will however be investigated further.

The distribution of DDT isomers identified in various samples in both plants is shown in Fig. 4.

### 3.2. DDT destruction

The feed point for hazardous wastes into a cement kiln should be selected according to the nature of the hazardous wastes to ensure a complete and irreversible destruction. In this study, the DDT powder and contaminated soil were fed through flue gas chamber at the kiln inlet, where the gas phase temperature is in the lower range, i.e., approximately 950–1050 °C. An important criterion for environmentally sound destruction is to achieve a sufficient DE and/or DRE. DE is calculated on the basis of mass of the DDT fed to the kiln, minus the mass of DDT in the stack emissions and in the solid samples according to Eq. (1). The DRE considers emissions to air only, according to Eq. (2).

$$DE(DDT, \%) = \left( \frac{M_p \times C_{DDT,P} \times 10^6 + M_{RM} \times C_{DDT,RM} \times 10^6 - M_{CK} \times C_{DDT,CK} \times 10^6 - M_{CKD} \times C_{DDT,CKD} \times 10^6 - V_G \times C_{DDT,G}}{M_p \times C_{DDT,P} \times 10^6 + M_{RM} \times C_{DDT,RM} \times 10^6} \right) \times 100\% \quad (1)$$

$$DRE(DDT, \%) = \left( \frac{M_p \times C_{DDT,P} \times 10^6 + M_{RM} \times C_{DDT,RM} \times 10^6 - V_G \times C_{DDT,G}}{M_p \times C_{DDT,P} \times 10^6 + M_{RM} \times C_{DDT,RM} \times 10^6} \right) \times 100\% \quad (2)$$

For the test burn with DDT powder, the feed rate ( $M_p$ ) of 1 t/h DDT powder with content ( $C_{DDT,P}$ ) of 10.63% amounts to 106.30 kg pure DDT per hour; the feed rate of RM ( $M_{RM}$ ) was 364.2 t/h with no DDT content ( $C_{DDT,RM}$ ), and the clinker ( $M_{CK}$ ) is 227.6 t/h with a DDT concentration of

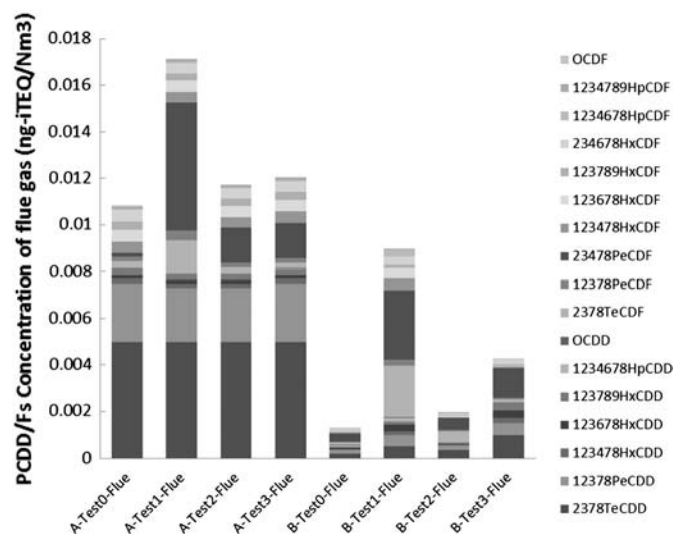


Fig. 5. PCDD/PCDF concentrations in flue gas from cement kilns A and B.

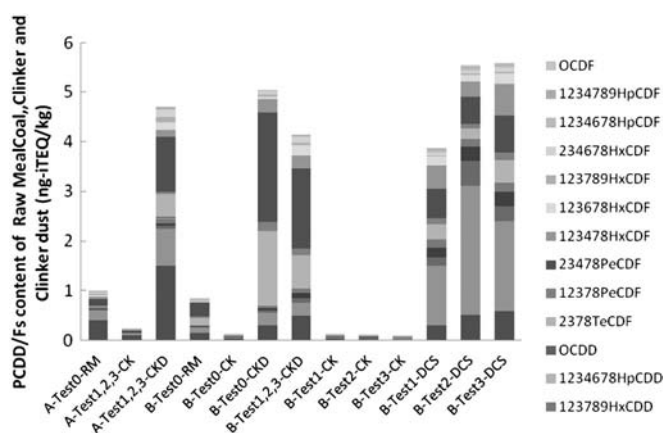


Fig. 6. PCDD/PCDF content of raw meal, clinker and cement kiln dust and contaminated soil from cement kiln co-processing.

( $C_{DDT,CK}$ ) 0.0682 ng/g; CKD ( $M_{CKD}$ ) is 22 t/h, the DDT concentration of CKD ( $C_{DDT,CKD}$ ) was 7.78 ng/g and the flue gas volume ( $V_G$ ) was 471,000 Nm<sup>3</sup>/h; and the average DDT concentration of flue gas ( $C_{DDT,P}$ ) was 30.00 ng/Nm<sup>3</sup>. The DE of DDT becomes 99.9998%, and the DRE 99.9999%.

For the test burn of contaminated soil, the feed rate of 0.833 t/h contaminated soil amounted to a feed of 1.12 kg DDT, 1.21 kg DDT and 2.83 kg DDT per hour, respectively; the feed rate of RM was 118 t/h with DDT content of 7.27 ng/g; the yield of clinker ( $M_{CK}$ ) is 74 t/h, the DDT concentrations of clinker ( $C_{DDT,CK}$ ) were 1.32 ng/g in B-Test1, 1.31 ng/g in B-Test2 and 0.21 ng/g in B-Test3, respectively; cement kiln dust ( $M_{CKD}$ ) is 7 t/h; the DDT concentration of cement kiln dust ( $C_{DDT,CKD}$ ) was averagely 89.2 ng/g; and the volume of flue gas ( $V_G$ ) was 200,000 Nm<sup>3</sup>/h. The DE of DDT was calculated to be average 99.9500%; the DREs of DDT were calculated to be 99.9992%.

### 3.3. Emission of PCDD/PCDFs and HCB

The PCDD/PCDF concentration in the flue gas in Plant A varied from the baseline of 0.011 ng I-TEQ/Nm<sup>3</sup> to 0.017, 0.012 and 0.012 ng I-TEQ/Nm<sup>3</sup> during feeding of the DDT powder.

The PCDD/PCDF concentration in the flue gas in Plant B varied from the baseline of 0.0013 ng I-TEQ/Nm<sup>3</sup> to 0.0090, 0.0019 and 0.0043 I-TEQ/Nm<sup>3</sup> when feeding contaminated soil. All the PCDD/PCDFs measurements are below the emission limits in U.S. EPA of 0.17 I-TEQ/Nm<sup>3</sup> (Federal Register, 1999) and the European Union and China of 0.1 ng I-TEQ/Nm<sup>3</sup>.

In accordance with the previous studies (UNEP, 2006; Karstensen et al., 2010), with relatively high temperature over 250 °C at the ESP inlet, high levels of PCDD/Fs are possibly generated, while there was no correlation between temperature and PCDD/Fs when operational temperature of ESP is lower than 250 °C. The inlet temperatures of the APCD in plants A and B are indicated in Table 1, i.e., 134 °C and 120 °C, respectively, which shall have little impact on PCDD/F formation.

The PCDD/F emission from cement kilns vary widely (Abad et al., 2004; Ames et al., 2012; Li et al., 2012a,b,d; Yang et al., 2012). These variations may stem from a combination of factors, including the design and operating conditions of the kiln and the fuels and raw materials fed into the kiln. PCDD/F concentrations between 0.002 and 0.042 ng I-TEQ/Nm<sup>3</sup> were reported in cement plant burning meat meal and used tires. For example, two measurements of PCDD/Fs under the same operating conditions for two different cement plants varied from 0.009 ng I-TEQ/Nm<sup>3</sup> (first measurement) to 0.002 ng I-TEQ/Nm<sup>3</sup> (second measurement) and from 0.026 ng I-TEQ/Nm<sup>3</sup> (first measurement) to 0.042 ng I-TEQ/Nm<sup>3</sup> (second measurement). Comparing with these findings, our data were similar with the previous studies.

The congener profile of PCDD/PCDFs of flue gas and solid samples are shown in Figs. 5 and 6, respectively.

Since both organic compounds and chlorine will be brought to the top of the preheater with the flue gas from the kiln, a sorption-desorption circulation process between flue gas and raw meal particle and dust particles at lower temperature at the top of the preheater may contribute to the formation of PCDD/PCDFs, PCBs and HCB (Karstensen et al., 2010; Sidhu et al., 2001).

The concentration of PCDD/PCDFs in solid samples from plants A and B shows 0.09–0.22 ng I-TEQ/kg for cement clinker, 4.1–5 ng I-TEQ/kg for CKD and 0.82–0.97 ng I-TEQ/kg for raw meal. The concentration of PCDD/PCDFs in contaminated soil ranged from 3.8 to 5.5 ng I-TEQ/kg.

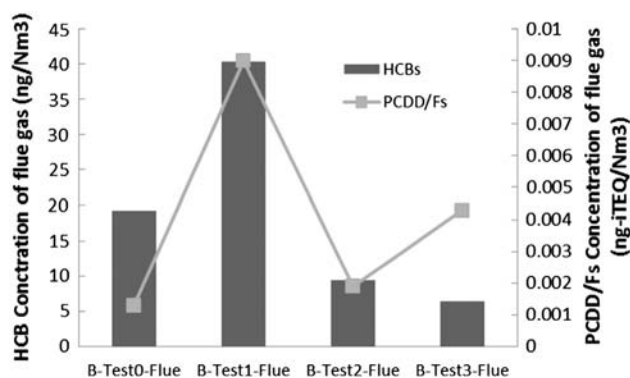


Fig. 7. Comparison of HCB with PCDD/PCDF concentration in flue gas.

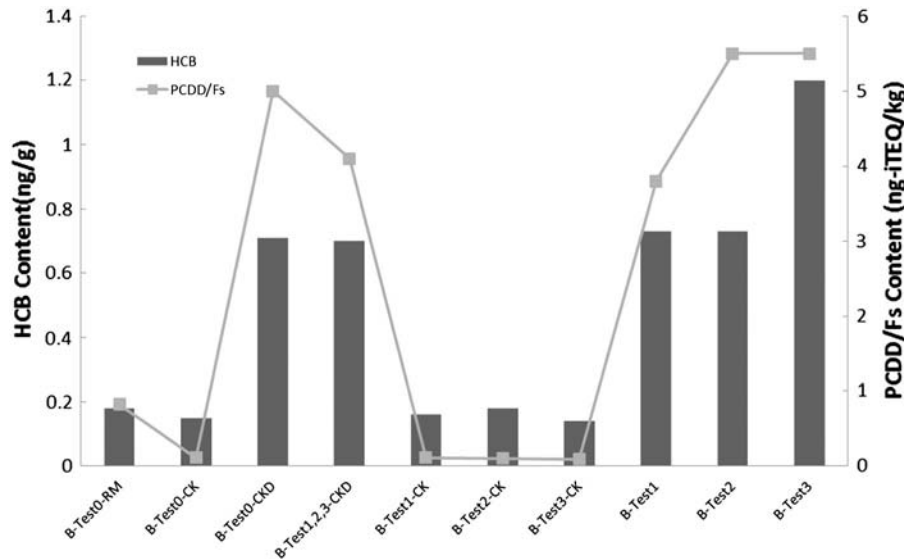


Fig. 8. Comparison of HCB with PCDD/PCDF concentration in solid material in clinker production.

Karstensen (2008) reviewed PCDD/PCDFs in solid materials from the cement industry, i.e., the average contents in raw meal, clinker and cement kiln dust are 1.4, 1.24 and 6.7 ng I-TEQ/kg, respectively.

HCB emission in flue gas and solid materials were only tested in test burn of contaminated soil. Fig. 7 illustrates that the HCB concentration is 19.3 ng/Nm<sup>3</sup> at blank condition, 40.4 ng/Nm<sup>3</sup> (B-Test1), 9.5 ng/Nm<sup>3</sup> (B-Test2) and 6.4 ng/Nm<sup>3</sup> (B-Test3).

There are limited reports of HCB content in solid material until now. Fig. 8 shows the HCB content of cement clinker in the range of 0.14–0.18 µg/kg, cement kiln dust in the range of 0.70–0.71 µg/kg, contaminated soil in the range of 0.73–1.2 µg/kg and raw meal of 0.18 µg/kg.

#### 3.4. Emission factors for PCDD/PCDFs and HCB

The emission factors for PCDD/PCDF and HCB in the flue gas are calculated by Eqs. (3) and (4), respectively.

$$EF(PCDD/Fs) = \frac{V_G \times C_{PCDD/Fs}}{M_{CK} \times 10^3} \quad (3)$$

$$EF(HCB) = \frac{V_G \times C_{HCB}}{M_{CK} \times 10^3} \quad (4)$$

The  $C_{PCDD/Fs}$  is the PCDD/PCDF concentration of flue gas. The PCDD/PCDF emission factor for flue gas is 0.0281 µg I-TEQ/t of test burn of DDT powder and 0.0137 µg I-TEQ/t for contaminated soil. Comparing with the emission factors PCDD/PCDF for flue gas of new dry suspension preheater rotary cement kiln of 0.05 µg/t in standardized computational toolkit (UNEP, 2005), it is shown that the emission factors is lower than the international average level (Chen, 2004). The HCB emission factor for flue gas varied in 17.32–109.34 µg/t.

#### 3.5. Impact of chlorine content on destruction on kiln system operation

During the co-processing of wastes in cement kilns, the chlorine content of raw meal, fuel and waste needs to be strictly controlled to avoid process clogging and adverse impact on the production process and cement product quality. When feeding the DDT powder and the contaminated soil, the chlorine input to the kiln system was 0.053 t and 0.0011–0.0028 t, equivalent to 0.013% and 0.0007% of the total throughput of the raw meal.

Ordinary quality testing was performed on cement produced from the tests, specific surface area, stability, initial and final setting time and the strength of the concrete after 1, 3 and 28 days. All the results were indicated in Table 2 within normal ranges and showed that the product quality was unaffected by the test burn with DDT powder and DDT contaminated soil.

**Table 2**  
The test of cement quality.

	Specific surface area (m <sup>2</sup> /kg)	Stability	Initial setting time (min)	Final setting time (min)	Rupture strength (Mpa)			Compressive strength (Mpa)		
					1d	3d	28d	1d	3d	28d
A-baseline	352.9	Qualified	89	125	—	6.7	—	—	34.2	—
A-DDT powder	354.6	Qualified	80	121	—	6.7	—	—	33.6	—
B-baseline	348	Qualified	113	153	3.0	6	8.3	17.1	34.4	53
B-DDT contaminated soil	366	Qualified	144	192	4.1	6.6	8.3	19.1	36.3	54

A-baseline: normal condition of plant A; A-DDT powder: DDT powder destruction in plant A; B-baseline: normal condition of plant B; B-DDT contaminate soil: DDT contaminated soil destruction in plant B.

“—,” not available.



#### 4. Conclusion

Test burns with DDT powder and DDT contaminated soil fed into the flue gas chamber at the cement kiln inlet in two modern preheater/precalciner cement kiln systems showed that the DDT had not been destroyed completely satisfactory. The DE and the DRE were 99.99997% and 99.99999%, respectively, when feeding DDT powder to kiln A, while the DE and the DRE were in the range of 99.9889%–99.9991% and 99.9983%–99.9997%, respectively, when feeding DDT-contaminated soil to kiln B.

The emission of PCDD/PCDFs in flue gas varied from 0.0019 to 0.0171 ng I-TEQ/Nm<sup>3</sup>, in compliance with Chinese, U.S. EPA and European Union regulation. The PCDD/PCDF emission factor for flue gas varied from 0.0137 to 0.0281 µg I-TEQ/ton clinker. The emission of HCB of flue gas varied from 0.0064 to 0.0404 µg/Nm<sup>3</sup>, and the subsequent emission factor varied from 17.32 to 109.34 µg/ton clinker.

The concentration of PCDD/PCDFs and HCB in solid samples decreased as follows: cement kiln dust, 4.1–5 ng I-TEQ/kg and 0.70–0.71 µg/kg respectively; >raw meal, 0.82–0.97 ng I-TEQ/kg and 0.18 µg/kg, respectively; and >cement clinker 0.09–0.22 ng I-TEQ/kg and 0.14–0.18 µg/kg, respectively.

The reason why we were able to detect every trace DDT under baseline conditions in both kiln systems will be investigated further, but it might be due to the fact that both kilns had been disposing similar waste materials in the period prior to our test and that DDT is actually building up and accumulating in the system, especially through recycling of cement kiln dust. DDTs, which are not entirely destroyed in this lower temperature part of the kiln system, will be adsorbed on dust particles at the post-preheater zone, trapped in the air pollution control equipment and recycled back through the raw meal silo and to the top of the preheater, creating an adsorption and desorption circulation that will bleed and emit DDT even when not feeding the waste.

This study indicates that the feeding of DDT and POPs-wastes to the lower temperature part of a cement kiln system possibly traces buildup and accumulates these compounds in the system, which might subsequently lead to emissions. The best international practice is to feed POPs to the high temperature part of the kiln, the main burner, i.e., the technical feasibility and environmental acceptability of this Chinese practice needs to be investigated thoroughly.

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