Name of Process: Vacuum Heating Decomposition	Status:
Vendor: Hoei-Shokai Co.Ltd Web site: http:// www.hoei-shokai.co.jp	Hoei-Shokai runs an industrial scale plant for separating Zn from Zn-plated steel at Toyota-city. In the plant, Zn-plated steel is heated under vacuum to evaporate Zn, and the Zn is recovered at metallic condition with high purity. Vacuum Heating Decomposition is one application of this vacuum technology for the environmental field. Since 1999, several Japanese government driven demonstration tests approved Vacuum Heating Decomposition. 1. In 1999, Hoei-Shokai carried out a small-scale demonstration test on DXNs contaminated soil cleaning for the Ministry of the Environment. The soils contained (a) 6300 pg-TEQ/g and (b) 5500 pg-TEQ/g of total DXNs were cleaned to (a) 0.0013 pg-TEQ/g and (b) 0.000082 pg-TEQ/g. 2. In 2001, Hoei-Shokai carried out a pilot scale demonstration test on DXNs contaminated soil cleaning using OPERA system (1ton/day capacity) for the Ministry of the Environment. The 200kg of soils containing 1000pg-TEQ/g were cleaned to (a) 0.00014 pg-TEQ/g at 1027K, (b) 0.34 pg-TEQ/g at 873K, and (c) 3.8 pg-TEQ/g at 673K respectively. 3. Hoei-Shokai carried out a pilot scale demonstration test using the OPERA system on Pesticides such as Chlordane, Aldrin, Dieldrin, Endrin, BHC, and PCNB (DDT, Heptachlor and HCB are also analyzed) for the Ministry of Agriculture, Forestry and Fisheries of Japan. Chlordane, BHC, and PCNB are decomposed above 99.9999% with 85-115% chlorine recovery requirement met. 4. In 2003, Hoei-Shokai carried out a pilot scale demonstration test using the OPERA system on PCBs contaminated soils for the Hyogo Prefectural Environment Create Center Public Corporation conducted. PCBs are decomposed above 99.9999%. 5. 2003-2005, Hoei-Shokai, Nagoya University, and City of Nagoya carried out the test for decomposing DXNs in the fly ash of MWI (Municipal Waste Incinerator).
Applicable Pesticides and related POPs wastes: Applicable chemicals: DXNs, PCBs, BHC, Chlordane, Aldrin, Endrin, PCNB, HCB	

Technology description:

Many remediation techniques for POPs have been developed. Since we have a successful technology of recovering zinc from zinc-plated steel by vacuum heating, we have applied this technique to decontaminate the contaminated POPs. In the early stage, two highly contaminated soil samples with PCDDs, PCDFs, and Co-PCBs were heated at 673, 873, 1073, 1273, and 1473K for four hours in a vacuum chamber at pressures from 0.5 to 1000 Pa. Concentrations of dioxins in the processed residues are found to be close to or lower than the detection limits. This Vacuum Heating Decomposition is now confirmed to be applicable to decompose POPs related pesticides. The amounts of POPs were observed at the various points in the system including the pumping line and found that their concentration levels are also much lower than the regulation levels. Furthermore, at these temperatures heavy toxic elements, such as Zn, Cd, and Pb, are found to evaporate from the soil samples and trapped as metals in the condenser cassette. Therefore, using the Vacuum Heating Technique, not only dioxins can be decomposed but also heavy metals can be removed from the soil.

This technique aimed at high cost-performance remediation which may be applicable for cleaning the pesticides and pesticides contaminated soils in large quantities, without pre-treatment such as POPs extraction and thus may cost less. Further, since materials evaporate at lower temperatures under vacuum than their boiling points, this technique is expected to become an energy-saving one.

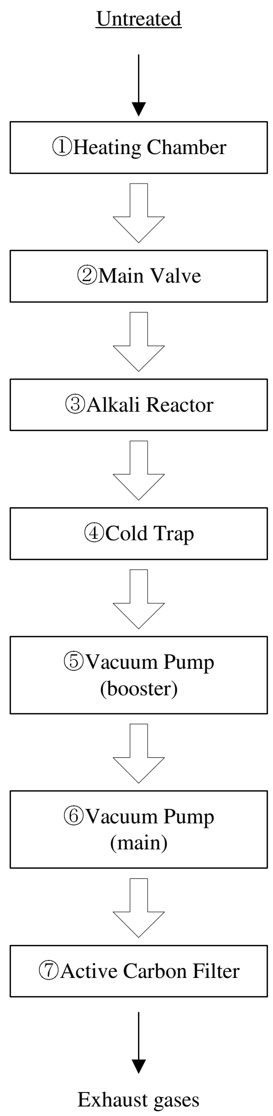
The principles of the Vacuum Heating Decomposition are as follows:

1. Heating the objects (such as pesticides) under vacuum condition
2. Pesticides and other POPs are decomposed by pyrolysis and de-chlorination reaction
3. Residual materials are almost inorganic
4. Gaseous fraction emitted by heating objects treated in the alkali reactor which is also under vacuum
5. Chlorine is fixed at alkali reactor as $CaCl_2$
6. Residual materials are cooled in the oxygen and chlorine free condition such as N_2 or vacuum

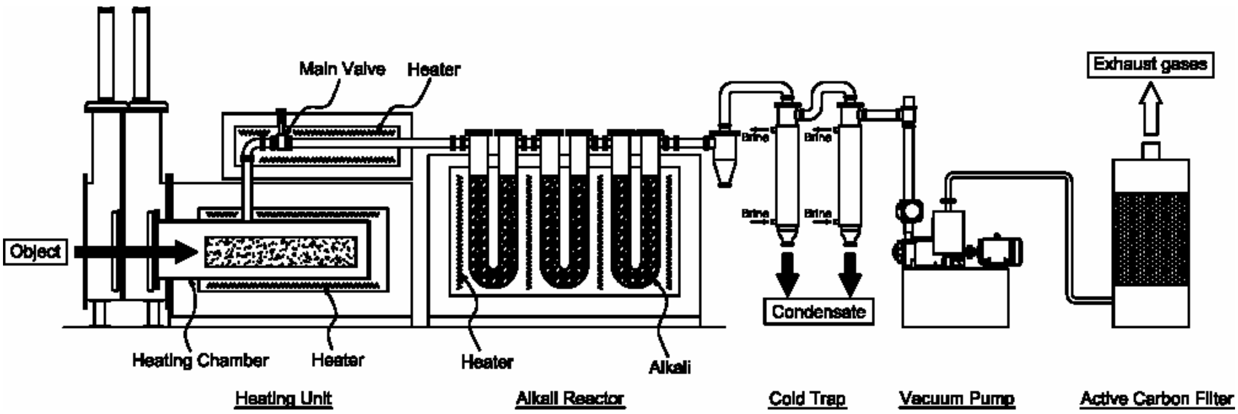
In the vacuum condition, a mean free path of the existing molecules is longer than that in the ambient. Therefore, synthesizing probabilities or re-synthesizing probabilities of pesticides and other POPs such as Dioxins are so small. On the other hand, an amount fixed in the residual materials is thought to be corresponding to partial pressures of POPs and their precursors. Therefore, residual materials are clean since partial pressures of POPs and precursors are small in the vacuum condition. In addition, the total amount of exhaust gas is small because the pressure of the gas is small. Due to this, the size of Vacuum Heating System is small and costs less. Different from methods employing metallic Na or super critical water, this Vacuum heating Decomposition is suitable for the bulk object such as pesticides and other POPs contaminated soils. In the vacuum condition, explosion can be prevented for there is almost no oxygen in the system.

Process diagram:

The Vacuum Heating Decomposition carried out by a system comprised of a main chamber for loading treating object, a pumping line connected to the main chamber. An alkali reactor and a condenser are intervened between the main chamber and the pumping line. The gaseous fractions emitted from the heated objects pass through the alkali reactor. Organic compounds emitted from the soil samples are pyrolyzed to smaller molecules and de-chlorination reaction also occurs. After the vacuum pumps, a charcoal filter is connected for absorbing POPs, if any. In order to prevent POPs from entering the pumping system, after the pesticides are loaded to the main chamber, the alkali reactor is heated to about 1073K, before heating of the pesticides is started. As the temperature of the object in chamber is raised, the pressure increases since the gaseous decomposition products are formed from the heated objects as well as in the alkali reactor. The pressure in the chamber varies with the sample temperature. The heating rate is regulated so that the pressure ranges from 0.5 to 2000 Pa.



OPERA System flow



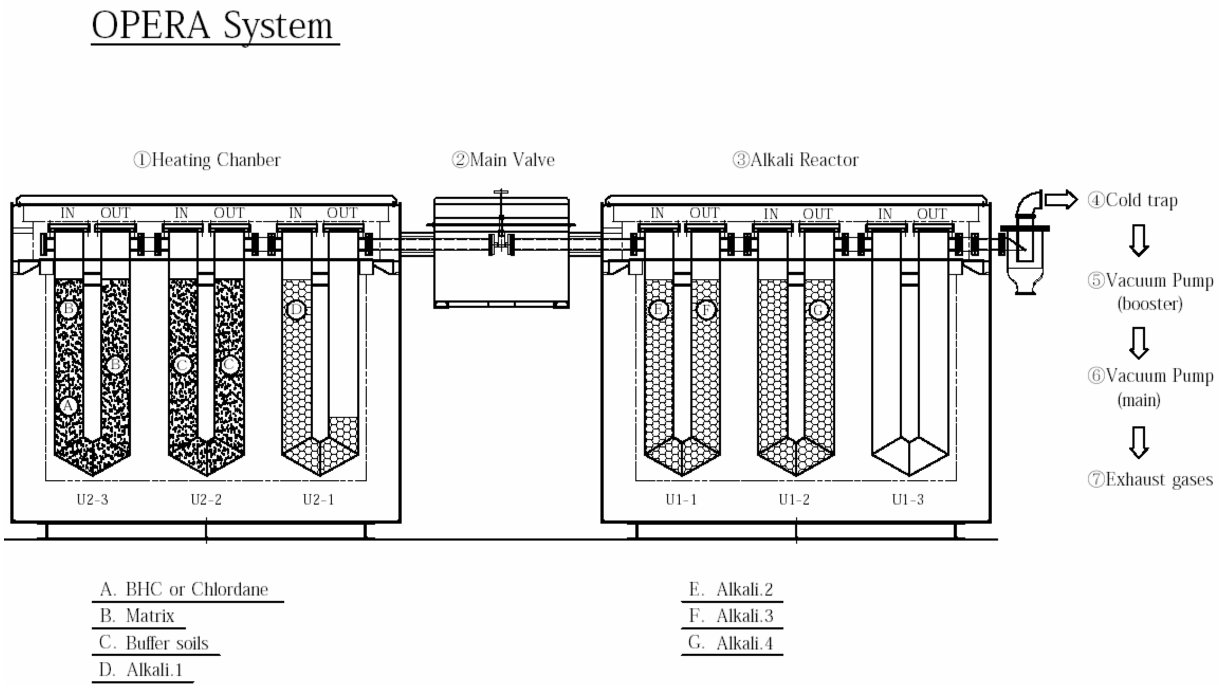
Performance:

Treatment efficiency:

1. Materials and Conditions of the demonstration tests

Pesticides to be treated	BHC	Chlordane
Conditions of Pesticides	Powder containing < 97 wt% BHC	Emulsion containing 95% Chlordane at 42%
Processing Temperature	1073 K	1073 K
Processing Pressure	Under Vacuum (10-3000Pa)	Under Vacuum (10-3000Pa)
Processing Duration	60min.	240min.
Processed Amount	1.5kg	1.5kg
Amount of Matrix (Soil)	50kg	50kg
Concentrations of Pesticides	3%（γ-BHC:2.83%）	3%（Chlordane:0.22%）

1. The demonstration tests for decomposing pesticides carried by using a pilot scale plant called OPERA (Onsite POPs Elimination and Remediation Apparatus) at Obayashi-Plant of Hoei-Shokai, Toyota-city. OPERA is a vacuum heating system designed for remediating POPs contaminated objects such as soils and fly ash. In this equipment, the object to be treated is heated under vacuum, and the gaseous fraction is processed in the pumping line. Since this demonstration test requires confirming severe mass balance, this test was carried out with sub-components attached with same principle.



2. Methods

In this test, we have applied Vacuum Heating Decomposition technique for pesticides such as Chlordane and BHC. In the heating chamber, 1.5 kg of BHC (1,2,3,4,5,6-Hexachlorocyclohexane, 97 % γ-BHC) are buried within the 50 kg of matrix. In this experiment, soils once processed at 1073 K under vacuum are used as a matrix to hold the BHC. This heating chamber is connected to the pumping line having vacuum pumps. Between the heating chamber and the vacuum pump, a buffer chamber, an alkali reactor and a condenser are connected in line. About 48 kg of processed soils in the heating chamber are also filled in the buffer chamber. A function of the buffer chamber is to control the emission rate of gaseous fraction to the pumping line. By employing this buffer, the vacuum heating technique is applicable not only for the inorganic objects but also for the organic rich objects such as pesticides. Total amount of alkali (CaO) filled in the alkali reactor is 201 kg. The condenser intervened between the alkali reactor and the vacuum pump is cooled by liquid Nitrogen. All the lines through the heating chamber to the cold trap are made of stainless-steel.

Before heating the BHC and the matrix, the alkali reactor is heated up to 1123 K. After the alkali reactor is reached 1073K, then the heating chamber is heated to 1073 K and maintained for 4 hours at the temperature. Gaseous fraction emitted from BHC during the process is passed through the buffer chamber and the heated alkali reactor. The gaseous fraction from the alkali reactor is cooled in the condenser.

After the experiment, analysis are made at the various points of the equipment including residue of the BHC and matrix, soils in the buffer, alkali, condenser, and exhaust gases. Not only theγ-BHC, but α-BHC, β-BHC, δ-BHC, PCDDs, PCDFs, and Co-PCBs, are analysed by HRGC/HRMS SIM. Analysis are carried by Shimadzu Tech. Research Co., Ltd.

For chlordane sample processing, the same manner is applied. In the 1.5 kg of sample, 7.4 % of chlordane (cis-chlordane: 4.1 %, trans-chlordane: 3.3 %) is included. For chlordane experiment, cis-chlordane and trans-chlordane are analysed.

3. Results

The summary of the demonstration tests on Pesticides conducted by the Ministry of Agriculture, Forestry and Fisheries of Japan, is as follows. As shown, all measured BHC isomers are not detected in respective fraction of the pilot plant. Detection limits for the residue, the buffer soils, and alkali are <0.0001mg/Kg. The detection limit for the cold trap is <0.00002mg/L, and for the exhaust gases is <0.0000005mg/m^3. Therefore, by the Vacuum Heating Decomposition, BHC is substantially decomposed substantially and no BHC isomers are synthesized.

The dioxins (PCDDs, PCDFs, and co-PCBs) concentrations in the test after the test are shown. Initially, no dioxins are detected from the BHC sample. However, the Vacuum Heating Decomposition forms small amount of dioxins formed although BHC is completely decomposed. Except the cold trap, the concentrations of synthesised dioxins in respective fraction are sufficiently low. This cold trap is employed for the reason that we would like to detect all the fraction emitted from the alkali reactor, and as a result, almost all Dioxins in the gas are condensed in the trap during the process. Note that no activated carbon filter is employed in the tests and emission gas sampled right after the vacuum pump. The pressure in the pilot plant is maintained vacuum through the process. Therefore, if the gas fraction from the alkali reactor is emitted to the atmosphere, the dioxins concentration would be much lower than the regulation level. In the actual situation for this process, any filter such as bag filter or charcoal filter may be equipped after the vacuum pump for promoting safety.

In the alkali reactor, only non chlorinated dibenzo-furan (DF) is detected though Tetra-Octa PCDDs/PCDFs are not detected. Smaller chlorinated congeners are remained in alkali reactor. A knowledge that the dechlorination reactions of dioxins occur in the Vacuum Heating Decomposition is confirmed in these two experiments for other POPs. In this BHC decomposition experiment, dibenzo-furan is detected but not dibenzo-para-dioxin (DD). Also, neither Mono-Tri, and Tetra-Octa chlorinated PCDFs nor PCDDs are remained in the alkali reactor. Different from the BHC, DD, DF and Mono-Di chlorinated PCDDs/PCDFs are remained, when the chlordane is processed. Observed congeners pattern suggests the different decomposition pathways exist for the BHC and chlordane.

Input POPs	DEs	DREs	Exhaust gases	Cold trap	Residue	Buffer soils	Alkari
%	%	%	mg/m^{3}N	mg/L	mg/kg	mg/kg	mg/kg
BHC 2.83	> 99.9999920	100.00000000	<0.0000020	<0.00008	<0.0004	<0.0004	<0.0004
Chlordane 0.22	> 99.9999404	> 99.99999999	<0.0000010	<0.00004	<0.0002	<0.0002	<0.0002

Table 1 ; Treatment efficiency of BHC and Chlordane

Medium		α-BHC	β-BHC	γ-BHC	δ-BHC	Total BHC	Detection Limit
Untreated (51.5kg)	%	<0.029	<0.029	2.83	<0.029	2.83	
BHC (1.5kg)	%	<1	<1	97	<1	97	
Matrix(50kg)		-	-	-	-	-	
Residue (49kg)	mg/kg	N.D.	N.D.	N.D.	N.D.	N.D.	0.0001mg/kg
Buffer soils (48kg)	mg/kg	N.D.	N.D.	N.D.	N.D.	N.D.	0.0001mg/kg
Alkali (200kg)	mg/kg	N.D.	N.D.	N.D.	N.D.	N.D.	0.0001mg/kg
Cold trap (6.707L)	mg/L	N.D.	N.D.	N.D.	N.D.	N.D.	0.00002mg/L
Exhaust gases (11.498m^3)	mg/m^{3}N	N.D.	N.D.	N.D.	N.D.	N.D.	0.0000005mg/m^3

Table 2 ; Summary of analysis made on the demonstration test for BHC by Vacuum Heating Decomposition

Medium		Cis-Chlordane	Trans-Chlordane	Total Chlordane	Detection Limit
Untreated (51.5kg)	%	0.12	0.096	0.22	
Chlordane (1.5kg)	%	4.1	3.3	7.4	
Matrix (50kg)		-	-	-	
Residue (50kg)	mg/kg	N.D.	N.D.	N.D.	0.0001mg/kg
Buffer soils(50kg)	mg/kg	N.D.	N.D.	N.D.	0.0001mg/kg
Alkali (228kg)	mg/kg	N.D.	N.D.	N.D.	0.0001mg/kg
Cold trap (6.240L)	mg/L	N.D.	N.D.	N.D.	0.00002mg/L
Exhaust gases (11.765m^3)	mg/m^{3}N	N.D.	N.D.	N.D.	0.0000005mg/m^3

Table 3 ; Summary of the analysis made on demonstration test for Chlordane by Vacuum Heating Decomposition

Medium		α-BHC	β-BHC	γ-BHC	δ-BHC	Total BHC
☐Untreated (51.5kg)	mg	<14,935	<14,935	1,457,450	<14,935	1,502,255
BHC (1.5kg)	mg	<14,935	<14,935	1,457,450	<14,935	1,502,255
Matrix (50kg)		-	-	-	-	-
☐Residue (49kg)	mg	<0.0049	<0.0049	<0.0049	<0.0049	<0.020
☐Buffer soils (48kg)	mg	<0.0048	<0.0048	<0.0048	<0.0048	<0.019
☐Alkali (200kg)	mg	<0.020	<0.020	<0.020	<0.020	<0.080
☐Cold trap (6.707L)	mg	<0.00013	<0.00013	<0.00013	<0.00013	<0.00052
☐Exhaust gases (11.498m^3)	mg	<0.0000057	<0.0000057	<0.0000057	<0.0000057	<0.000023
☐Total Input (☐)	mg	<14,935	<14,935	1,457,450	<14,935	1,502,255
☐Total Output (☐+☐+☐+☐+☐)	mg	<0.030	<0.030	<0.030	<0.030	<0.12
☐Destruction efficiency (1-☐/☐×100)	%	-	-	-	-	>99.9999920

Table 4 ; Amount of BHC isomers in respective fractions

Medium		Cis-Chlordane	Trans-Chlordane	Total Chlordane
□Untreated (51.5kg)	mg	61,800	49,440	111,240
Chlordane (1.5kg)	mg	61,800	49,440	111,240
Matrix (50kg)		-	-	-
□Residue (50kg)	mg	<0.0050	<0.0050	<0.010
□Buffer soils (50kg)	mg	<0.0050	<0.0050	<0.010
□Alkali (228kg)	mg	<0.023	<0.023	<0.046
□Cold trap (6.240L)	mg	<0.00012	<0.00012	<0.00024
□Exhaust gases (11.765m^3)	mg	<0.0000059	<0.0000059	<0.000012
□Total Input (□)	mg	61,800	49,440	111,240
□Total Output (□+□+□+□+□)	mg	<0.033	<0.033	<0.066
□Destruction efficiency (1-□/□×100)	%	-	-	>99.9999404

Table 5 ; Amount of Chlordane isomers in respective fractions

Medium		PCDDs/PCDFs	Co-PCB	Total Dioxins
Untreated (51.5kg)	pg-TEQ/g	0	0	0
BHC (1.5kg)	ng-TEQ/g	0	0	0
Matrix (50kg)	pg-TEQ/g	0	0	0
Residue (49kg)	pg-TEQ/g	0.43537	0.00009	0.44
Buffer soils (48kg)	pg-TEQ/g	1.8591	0.00024	1.9
Alkali.1 (10kg/41kg)	pg-TEQ/g	0	0.00094	0.00094
Alkali.2 (10kg/39kg)	pg-TEQ/g	0	0.00034	0.00034
Alkali.3 (10kg/40kg)	pg-TEQ/g	0	0.00076	0.00076
Alkali.4 (10kg/40kg)	pg-TEQ/g	0	0.00052	0.00052
Cold trap (6.707L)	pg-TEQ/L	129.7	37.1118	170
Exhaust gases (11.498m^3)	ng-TEQ/m^3	0.0009539	0.001924182	0.0029

Table 6 ; DXNs (Tetra-Octa chlorinated) concentration in respective fractions before and after the BHC decomposition process

Medium		PCDDs/PCDFs	Co-PCB	Total Dioxins
Untreated (51.5kg)	pg-TEQ/g	0.2145	0	0.21
Chlordane (1.5kg)	ng-TEQ/g	0.00703	0	0.0070
Matrix (50kg)	pg-TEQ/g	0.010	0	0.01
Residue (50kg)	pg-TEQ/g	0.01217	0.00008	0.012
Buffer soils (50kg)	pg-TEQ/g	0.02085	0.00009	0.021
Alkali.1 (10kg/41kg)	pg-TEQ/g	0.009	0.00292	0.012
Alkali.2 (10kg/40kg)	pg-TEQ/g	0.01115	0.00414	0.015
Alkali.3 (10kg/40kg)	pg-TEQ/g	0.02119	0.00312	0.024
Cold trap (6.240L)	pg-TEQ/L	1534.45	147.508	1700
Exhaust gases (11.765m^3)	ng-TEQ/m^3	0.0219326	0.01050995	0.032

Table 7 ; DXNs (Tetra-Octa chlorinated) concentration in respective fractions before and after the Chlordane decomposition process

Medium		Organic-Cl	Inorganic-Cl	Total-Cl
☐Untreated (51.5kg)	mg	1,023,055	420	1,023,475
BHC (1.5kg)	mg	1,023,000	0	1,023,000
Matrix (50kg)	mg	55	420	475
☐Residue (49kg)	mg	299	11,270	11,569
☐Buffer Soils (48kg)	mg	115	30,240	30,355
☐Alkali (200kg)	mg	53	933,316	933,369
☐Cold Trap (6.707L)	mg	280	300	580
☐Exhaust Gases (11.498m^3)	mg	0	0	0
☐Total Input（☐）	mg	1,023,055	420	1,023,475
☐Total Output（☐+☐+☐+☐+☐）	mg	747	975,126	975,873
☐Balance（☐/☐×100）	%			95.3

Table 8 ; Chlorine recovery for confirming mass balance through the BHC decomposition process

Medium		Organic-Cl	Inorganic-Cl	Total-Cl
☐Untreated (51.5kg)	mg	372,016	1,850	373,866
Chlordane (1.5kg)	mg	372,000	-	372,000
Matrix (50kg)	mg	26	1,850	1,866
☐Residue (50kg)	mg	35	70,000	70,035
☐Buffer Soils (50kg)	mg	39	29,000	29,039
☐Alkali (228kg)	mg	294	243,124	243,418
☐Cold Trap (6.240L)	mg	0.38	330	330
☐Exhaust Gases (11.765m^3)	mg	0.062	0.87	0.93
☐Total Input（☐）	mg	372,016	1,850	373,866
☐Total Output（☐+☐+☐+☐+☐）	mg	368	342,455	342,823
☐Balance（☐/☐×100）	%	0.099	18,511.10	91.7

Table 9 ; Chlorine recovery for confirming mass balance through the BHC decomposition process

4. Related information for the Vacuum Heating Decomposition

The result of a pilot scale demonstration test using PCNB

Medium		PCNB
☐Untreated (1000g)	μg/g	30,000
PCNB (150g)	μg/g	200,000
Matrix (850g)	μg/g	-
☐Residue (927g)	μg/g	<0.01
☐Alkali (28kg)	μg/g	<0.01
☐Cold trap (Total)	μg/L	<0.1
☐Exhaust gases (3.037m^3)	μg/m^3N	0.07

Table 10 ; Summary of analysis made on the demonstration test for PCNB by Vacuum Heating Decomposition

Medium		PCNB
☐Untreated (1000g)	μg	30,000,000
PCNB (150g)	μg	30,000,000
Matrix (850g)	μg	-
☐Residue (927g)	μg	0
☐Alkali (28kg)	μg	0
☐Cold trap (Total)	μg	0
☐Exhaust gases (3.037m^3)	μg	0.21
☐Total Input (☐)	μg	30,000,000
☐Total Output (☐+☐+☐+☐)	μg	0.21
☐Destruction efficiency (1-☐/☐×100)	%	100

Table 11 ; Amount of PCNB in respective fractions

Medium		HCB
☐Untreated (1000g)	μg/g	960
PCNB (150g)	μg/g	6,400
Matrix (850g)	μg/g	-
☐Residue (927g)	μg/g	<0.01
☐Alkali (28kg)	μg/g	<0.01
☐Cold trap (Total)	μg/L	<0.1
☐Exhaust gases (3.037m^3)	μg/m^{3}N	0.25

Table 12 ; Summary of the analysis made on demonstration test for Chlordane by Vacuum Heating Decomposition

Medium		HCB
☐Untreated (1000g)	μg	960,000
PCNB (150g)	μg	960,000
Matrix (850g)	μg	-
☐Residue (927g)	μg	0
☐Alkali (28kg)	μg	0
☐Cold trap (Total)	μg	0
☐Exhaust gases (3.037m^3)	μg	0.76
☐Total Input (☐)	μg	960,000
☐Total Output (☐+☐+☐+☐)	μg	0.76
☐Destruction efficiency (1-☐/☐×100)	%	100

Table 13 ; Amount of HCB in respective fractions through the PCNB decomposition test

Medium		PCDDs/PCDFs	Co-PCB	Total Dioxins
☐Untreated (1000g)	pg-TEQ/g	-	-	300
PCNB (150g)	ng-TEQ/g	-	-	2000
Matrix (850g)	pg-TEQ/g	0.0868	0	0.087
☐Residue (927g)	pg-TEQ/g	2.8756	0.00019	2.9
☐Alkali (28kg)	pg-TEQ/g	0	0.00097	0.00097
☐Cold trap (Total)	pg-TEQ/L	26.61	41.2248	68
☐Exhaust gases (3.037m^3)	ng-TEQ/m^3	0.01605	0.03154	0.048

Table 14 ; DXNs (Tetra-Octa chlorinated) concentration in respective fractions before and after the BHC decomposition process

Medium		PCDDs/PCDFs	Co-PCB	Total Dioxins
☐Untreated (1000g)	ng-TEQ	-	-	300
PCNB (150g)	ng-TEQ	-	-	300
Matrix (850g)	ng-TEQ	0.07378	0	0.074
☐Residue (927g)	ng-TEQ	2.6656812	0.00017613	2.7
☐Alkali (28kg)	ng-TEQ	0	0.02716	0.027
☐Cold trap (Total)	ng-TEQ	0.02661	0.0412248	0.068
☐Exhaust gases (3.037m^3)	ng-TEQ	0.04874385	0.09578698	0.15
☐Total Input (☐)	ng-TEQ	-	-	300
☐Total Output (☐+☐+☐+☐)	ng-TEQ	2.74103505	0.16143791	2.9
☐Destruction efficiency (1-☐/☐×100)	%			99.0

Table 15 ; Amount of DXNs in respective fractions through the PCNB decomposition test

Medium		Organic-Cl	Inorganic-Cl	Total-Cl
☐Untreated (1000g)	μg	-	-	18,000,000
PCNB (150g)	μg	-	-	18,000,000
Matrix (850g)	μg	0	0	0
☐Residue (927g)	μg	0	1,297,800	1,297,800
☐Alkali (28kg)	μg	0	14,000,000	14,000,000
☐Cold trap (Total)	μg	0	0	0
☐Exhaust gases (3.037m^3)	μg	0	0	0
☐Total Input (☐)	μg	-	-	18,000,000
☐Total Output (☐+☐+☐+☐)	μg	0	15,297,800	15,297,800
☐Balance (☐/☐×100)	%			85.0

Table 16 ; Chlorine recovery for confirming mass balance through the PCNB decomposition process

Throughput:

Hoei-Shokai runs two plants for remediating POPs and POPs contaminated soils.

1. Pilot scale plant: 1 ton/day for POPs contaminated soils, Pesticides. The plant is a mobile type, but now set in the Obayashi-Plant in Toyota-city.

2. Commercial scale plant: 10 ton /day for POPs contaminated soils. The plant is non-mobile type, set in the Obayashi-Plant in Toyota-sity.

Wastes/Residuals:

Residue:
Residual soil and other materials met requirements for disposal. Inorganic residual soils can be mixed with composts for reuse as agricultural soils.

Alkalis:
Residual Alkali (CaO and $CaCl_2$) is one of the end products of the Vacuum Heating Decomposition. As shown above, this residual alkali met requirement for disposal.

Condensed Liquids:
Water is condensed in the cold trap and this Liquid fraction sometimes may contain regulation border level of DXNs. This fraction usually dried up to 373K and re-processed in the Vacuum Heating Decomposition.

Exhaust Gases:
Gas fraction met requirement for exhaust to atmosphere. At Hoei-Shokai, activated carbon filters and oxidizing catalysts are employed for promoting safety.

Reliability:
Hoei-Shokai runs the commercial scale Vacuum Heating plant (for metal recycle) for seven years. From 2004, Hoei-Shokai begins commercial operation for POPs related pesticides.

Limitations:

Conditions of Pesticides:
Pesticides can be treated in paper or plastic packages, or unopened bottles. Also, pesticides buried within the concrete can be treated as is. Soils, stones, roots, steel, ceramics cleaned with pesticides without separation.
Concentration of pesticides does not affect the decomposition (1.5kg of BHC samples (99.7wt.%) was decomposed at 99.9999%).
Relatively Dry condition (up to 30%) is preferred, but water content is not a crucial parameter.

Transportability:
Pilot scale plant OPERA is mobile one, which has pre-fabric concept and is designed for transportation.

Detailed information:
No Annex

Conclusion:
Vacuum Heating Decomposition is a technique

Full Scale Treatment examples:
No information is available at present, however from 2004, Hoei-Shokai begins commercial operation for POPs related pesticides.

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Patents:
Hoei-Shokai Co.Ltd has two patents in Japan.

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