

Philippines

Dioxin and Furan Emission Testing

A Test Trial of the GTZ - Holcim Alliance
and the
Union Cement Corporation

REPORT

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April 2005

1 Project Outline

In order to establish a better basis for the co-processing of alternative fuels and raw materials (AFR) in cement kilns in the Philippines a trial burn was proposed to measure the unintentional by-products, polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), in the stack emissions. A test trial was carried out in the Bulacan cement plant of the Union Cement Corporation in the Philippines.

The project was an activity of the Strategic Alliance of Holcim and the GTZ to promote and support the co-processing and the disposal of waste materials in cement kilns.

1.1 Background

In nearly all developing countries there are no facilities for a safe and environmentally sound disposal of waste - especially for hazardous chemicals. Hazardous waste is generally managed without safe disposal. As a consequence, soil, water and air are contaminated, so that living conditions deteriorate and public health is threatened.

The cement industry offers an alternative form of treatment known as co-processing. Within this process high calorific waste can be used as alternative fuels and raw materials (AFR) in the cement kilns in place of fossil fuels. In many countries this method constitutes an environmentally and economically attractive and safe solution to the problem of waste treatment. In addition, CO₂ emissions are reduced, with consequent benefits for the global climate. In all incineration processes special attention must be paid to the formation of polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) as unintentional by-products of chlorine and hydrocarbon precursors from the raw materials are available in sufficient quantities.

The formation of dioxins and furans is known to occur by “de novo synthesis” within the temperature range of cooling from 450 to 200 °C. It could happen during the co-processing of halogenated waste in a cement kiln.

Due to the long residence time in the kiln and the high temperatures, emissions of PCDDs and PCDFs are generally low during steady kiln conditions. In Europe, cement production is rarely a significant source of PCDD/F emissions. The reported data indicate that cement kilns can mostly comply with an emission concentration of 0.1 ng I-TEQ¹/Nm³, which is the limit value in the European legislation for hazardous waste incineration plants (*Council Directive 2000/76/EC*). Researches in Germany² during the last 10 years indicate that the average PCDD/F concentration amounts to about 0.02 ng I-TEF³/m³ (Table 1).

¹ I-TEQ = International Toxic Equivalent factor based on 2,3,7,8-TCDF

² Integrated Pollution Prevention and Control (IPPC): Reference Document on the Best Available Technology in Cement and Lime Manufacturing Industries, 12/2001

³ TEF = Toxic Equivalent Factor

Table 1

Dioxins and Furans

Two groups of related chlorinated aromatic dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are known; they consist of a total of 210 individual substances (congeners): 75 PCDDs and 135 PCDFs.

PCDDs and PCDFs can be formed during the combustion of organic materials; they also may occur as undesirable by-products in the manufacture or further processing of chlorinated organic chemicals. PCDDs/PCDFs enter the environment via these emission paths and through the use of contaminated materials. In fact, they are universally present in very small concentrations. The 2,3,7,8-chlorine substituted congeners are toxicologically significant. Toxicologically much less significant than the tetrachlorinated to octachlorinated dibenzodioxins/dibenzofurans are the 74 monochlorinated to trichlorinated dibenzodioxins / dibenzofurans.

17 of the 210 (PCDDs/PCDFs) congeners are considered potentially harmful to humans. These 17 dioxin/furan congeners shall be measured and quantified.

| PCDD/PCDF Congeners | I-TEF | |
|---------------------|-------|-----------------------------|
| 2378 TCDF | 0.1 | Tetrachlorodibenzofuran |
| 2378 TCDD | 1 | Tetrachlorodibenzofuran |
| 12378 PeCDF | 0.05 | Pentachlorodibenzofuran |
| 23478 PeCDF | 0.5 | |
| 12378 PeCDD | 0.5 | Pentachlorodibenzo-p-dioxin |
| 123478 HxCDF | 0.1 | Hexachlorodibenzofuran |
| 123678 HxCDF | 0.1 | |
| 234678 HxCDF | 0.1 | |
| 123789 HxCDF | 0.1 | |
| 123478 HxCDD | 0.1 | Hexachlorodibenzo-p-dioxin. |
| 123678 HxCDD | 0.1 | |
| 123789 HxCDD | 0.1 | |
| 1234678 HpCDF | 0.01 | Heptachlorodibenzofuran |
| 1234789 HpCDF | 0.01 | |
| 1234678 HpCDD | 0.01 | Heptachlorodibenzo-p-dioxin |
| OCDF | 0.001 | Octachlorodibenzofuran. |
| OCDD | 0.001 | Octachlorodibenzo-p-dioxin |

Ref.: European Standard EN 1948-2:1996

1.2 Objective of the Dioxins/Furans Test Trial

The objective of this trial burn is to demonstrate that the emissions resulting from the use of a halogen containing organic waste as alternative fuel in the Bulacan Cement Plant can comply with international standards for dioxins and furans, like the regulations of the European Community (EC).

In evaluating compliance, reference shall be made to for dioxin and furan emissions of 0.10 I-TEQ ng/Nm³ of the *Directive 2000/76/EC* on the incineration of waste of the European Community.

1.3 Strategic Alliance – Partners for Development

To introduce, promote and support the co-processing and the use of waste materials in cement factories around the globe, the German Technical Cooperation (GTZ), Germany, has joined forces with Holcim, one of the world's leading suppliers of cement in form of a public-private partnership (PPP). This Strategic Alliances will develop and test internationally acceptable guidelines for the use of waste materials in cement plants in pilot projects in countries in which both companies are active: Chile, Mexico, Morocco and The Philippines.

The pilot projects will enable testing of the developed guidelines and compile experience with co-processing on the local level. The nature of the tasks undertaken is determined by local conditions, with the focus on legislation, awareness raising and carrying out test trials to demonstrate the strength of the co-processing.

1.4 Trial Burn and the Measurements of Dioxins and Furans

Two cement plants in the Philippines have been granted Environment Compliance Certificates allowing to use AFR, while work on drafting guidelines on co-processing⁴ has started.

With dioxins and furans being a key concern of stakeholders, a trial burn in which these substances were measured, was conducted in the Bulacan cement plant of the Union Cement Corporation, a company of the Holcim Group.

2 Methods

2.1 Trial Burn and the Dioxins/Furans Emission Measurement

The test trial was performed jointly by the Bulacan Cement Plant, the AirLabs Pty. Ltd⁵., Australia, the Industrial Technology and Development Institute (ITDI) of the Department of Science and Technology, and the GTZ Project Chemical Safety, Germany.

⁴ "Guidelines on Co-processing Waste Materials in Cement Production"; from the Strategic Alliance of Holcim and the GTZ.

⁵ AirLabs Pty. Ltd., 149 Bryants Rd., Loganholme, Queensland, 4129 Australia

The AFR officers of the Bulacan cement plant were responsible for the management and execution of the trial burn. AirLabs Pty. Ltd., a commercial company for environment monitoring services, was commissioned to perform the sampling of the stack gas emission during the test phase and the PCDDs and PCDFs analyses.

The work was monitored by an expert of the Project Chemical Safety of GTZ to ensure compliance with the respective quality assurance /quality control (QA/QC) and the protocol, which was co-developed by ITDI and Union Cement, for the measurement of stack gas emissions when using waste as alternative fuel (co-processing). Personnel from ITDI⁶ and from the Department of Environment and Natural Resources- Environment Management Bureau were likewise present to monitor the test.

2.2 The Bulacan Cement Plant

The Bulacan cement plant of the Union Cement Corporation is situated in Norzagaray Bulacan, around 60 Km North of Metro Manila, on the Island of Luzon.



The Bulacan cement plant



The rotary kiln

The cement plant consists of a rotary kiln of 80 m length and a diameter of 5.0 m, four cyclones and two pre-heaters - an inline calciner (ILC) and a separate line calciner (SLC). The kiln is heated with coal. The maximum capacity of the plant is 5.500 tons clinker per day.

2.3 The Bulacan Co-processing Facility

The Bulacan cement plant is equipped with a semi-automatic facility for co-processing of solid, liquid, and sludge wastes as alternative fuel and/or raw materials (AFR).

⁶ Industrial Technology Development Institute (Philippines)

For solids, the co-processing facility is semi-automatic. The units consist of a big feeding hopper and a conveyer, which conveys the solid waste to the riser duct below the inline calciner (ILC) directly. From there the AFR will be introduced into the kiln on the secondary side. The hopper has to be loaded manually.



The feeding hopper



The conveyer runs in the angular tunnel

The main equipment for the recovery of energy and minerals from waste materials is the cement kiln. The co-processing process takes place while the kiln is producing clinker, the pre-product of cement. Waste materials with energy content are used as alternative fuel while those with minerals are used as alternative raw material. High temperature process ensures that emissions are compliant with local and international standards, including those for dioxins and furans.

2.4 Conditions for the Test trial

A protocol with the criteria for the test trial for measuring dioxin and furan emissions in the stack gas has been worked out and agreed on by all parties. According to this protocol the test trial must be in compliance with international regulations and procedures, like the "USEPA Codes of the Federal Regulations (CFR) 40" and the "EU Directive 2000/76 EC on the incineration of waste".

2.4.1 The test trial included the following parameters

- A blanc test run (without AFR),
- A test run with a feeding rate of 1.75 tons pet food/hour,
- A test run with a feeding rate of 3.5 tons pet food/hour,

- The cement kiln (cement plant) should be run in the “Compound mode⁷”,
- The sampling time of the stack gas should be between 6 - 8 hours per run,
- The stack gas sampling starts only after all process parameters of the cement kiln have been stabilized (information from the control room),
- During the test trial, all normal sampling procedures of clinker, bag filter dust, coal, kiln feed and pet food must be sampled and analyzed,
- Continuous monitoring of the standard operating parameters
- Continuous emission monitoring of the standard parameters CO₂, CO, O₂, NO_x, SO_x, HCL, moisture; NH₃ VOC and dust,
- Gathering of all process data and conditions during the test trial

2.4.2 Qualifications for the sampling and analysis of the stack gas emission

For the performance of the stack gas sampling and analysis to get reliable results the following qualified test methods of the U.S. Environmental Protection Agency have been used:

- USEPA Method 1 - Sample and Velocity Traverses for Stationary Sources (40 CFR Part 60),
- USEPA Method 2 - Determination of Stack Gas Velocity and Volumetric Flow Rate (CFR Part 60, Appendix A),
- USEPA Method 3A - Gas Analysis for Carbon Dioxide, Oxygen, Excess Air, and Dry Molecular Weight (40 CFR Part 60, Appendix A),
- USEPA Method 4 - Determination of Moisture Content in Stack Gases (40 CFR Part 60, Appendix A),
- USEPA Method 5 - Determination of Particulate Matter Emissions from Stationary Sources (40 CFR Part 60, Appendix A).
- USEPA Method 23 - Determination of Polychlorinated Dibenzo-p-Dioxines and Polychlorinated Dibenzofurans.

3 Test material

For testing the stack gas emissions for dioxins and furans during a co-processing of an AFR waste in a large quantity with a homogeneous composition as well as a high chlorine (halogen) content was necessary.

During the beginning of the planning phase for the test trial, expired medicines and their packaging materials were chosen as test material. One Pharmaceutical

⁷ Compound mode: The cement kiln runs under normal condition with the vertical raw mill running.

company in the Philippines agreed to supply the material for the test, because this material was classified as hazardous waste (category M505). The expired medicines are normally packed in PVC-foils, which contains certain content of chlorine. At the end, the Pharmaceutical companies could not provide sufficient quantity of homogeneous waste for the test trial. As an alternative recalled pet food was chosen for the test.

3.1 AFR Profile

The pet food is produced from cereals, meat and meat derivatives, vegetable derivatives and other ingredients, and is in the form of small pellets. The product was packed in 20 kg paper bags.

The local distributor recalled a batch of more than 1200 tons of this imported pet food as a quality assurance measure, upon learning that mold toxins found at the Thailand factory were the most likely cause of the increase in renal illness among dogs.

Pet food is not a typical hazardous waste and normally not used as AFR for co-processing. In this case the pet food was suitable for co-processing, because

- With 1200 tons of pet food a large quantity of one homogeneous product were ready for disposal,
- The calorific value of the pet food has been evaluated with 4600 MJ⁸ – the calorific value is high enough to use the pet food as AFR for co-processing and
- The chlorine content of the pet food is sufficient for this test trial.



3.2 Analytical results of the pet food

The chlorine content of the pet food was 1, 28 % chloride (according to the modified Volhard method). In comparison, the chloride content of coal used in the Bulacan plant is only in the range of nil to 0.08%. This means during the co-processing an additional halogen compound (chlorine) will be introduced into the cement kiln (Annex 1).

The increase of the chlorine content in the cement making process increases also the probability of the formation of unintentional by-products. The pet food

⁸ The calorific value of the coal from Indonesia is 6240 MJ.

delivered chlorine and hydrocarbon in sufficient quantities for the formation of PCDDs/PCDFs according to the “de novo synthesis”.

Under this circumstance it was possible to use the pet food for testing the emissions of the stack gas for dioxins and furans.

4 The Test trial

The test trial was carried out in the period from the 21st – 23rd November 2004 in the Bulacan cement plant, the

- Blanc test run (without AFR) - 21st November,
- Test run 1 with a feeding rate of 1.75 tons / hour – 22nd November, and
- Test run 2 with a feeding rate of 3.5 tons / hour – 23rd November.

4.1 The Co-processing

The pet food was loaded manually into the hopper by the workers. The workers had to carry the paper bags from the containers to the hopper. They opened the bags and poured the pellets into the hopper. From the hopper the conveyer transported the AFR material to the inline-calciner (ILC) and from there the pellets were directly introduced into the secondary side of the cement kiln.



Loading of the hopper

The adjustment of the feeding rate of the conveyer was difficult. The feed rate had to be adjusted manually by measuring the quantity of the pet food per bucket and the running time of the conveyer.

The loading of the hopper was a dusty undertaking. Under the consideration that the pet food was contaminated with moulds, the workers were required to wear protecting gear, especially dust masks⁹.

⁹ According to the requirements of the Occupational Health and Safety (OH&S) regulations the use of safety gears is an obligation for all employees working with AFR.



The sampling of the stack gas started only after the control room confirmed that the kiln and all process parameters have been stabilized. This was usually the case one hour after the start of the feeding of AFR.

Bucket of the conveyer with pet food

4.2 Description of the Stack Gas Sampling Procedures

The commercial analytical Laboratory AirLabs Pty. Ltd. was commissioned by the Union Cement Corporation¹⁰ and the GTZ to analyze the stack gas emissions during the test trial in the Bulacan Cement Plant.

The following parameters had to be measured concerning the standard procedures of the performance of the stack gas sampling and analysis of the dioxins and furans emissions (see 2.4.2):

- The gas velocity and volume flow rate
- Temperature
- Concentration of moisture
- Concentration of oxygen and
- Concentration and emissions rate of dioxins and furans.

4.3 Measuring conditions and results

The three test trials were carried out in series, one test trial per day. Sampling started only after the conditions in the kiln have been stabilized, approximately +/- 1 hour after the start of the feeding of AFR material. For each test run the stack gas was sampled during a period of “a minimum 6 hours” at the four sampling port locations on the platform of the chimney in 32 m height.



The chimney with the monitoring platform

¹⁰ On behalf of the Union Cement Corporation (UCC) the AirLabs Pty. Ltd. carried out an additional dioxins/furans monitoring program in other cement plants of company – in the cement plants “La Union, Lugait and Davao”.

4.4 Dioxins and Furans Sampling Procedure

Two experts of the AirLabs carried out the sampling of the stack gases. The sampling was monitored by an expert of the GTZ. The sampling of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzo-p-furans (PCDFs) were performed in accordance with the USEPA Method 23.



Installation of the tempered probe in one of the four sampling points

The principle of the method is that a sample of a stack gas is withdrawn isokinetically from the gas stream on one of the sampling points of the chimney with a tempered probe (picture). The gas stream has to pass the combined condenser, which contains a filter and an absorbent. The dioxins and furans are absorbed in the absorbent trap which contains 40 grams of an absorbent material.



The combined condenser with absorbent trap

4.4.1 Temperature; Gas Velocity and Volume Flow Rate

The positions of the probe for the measurements of the velocity, pressure and temperature were determined in accordance with USEPA Method 1 where the gas velocity and volume flow rates were calculated in accordance with USEPA Method 2.

The gas velocity profiles were obtained across the sampling plane using a S-type pitot / K-type thermocouple probe linked to a TCR Tecora Flowtest calculator. According to the information from AirLabs the estimated accuracy is +/- 1 °C for temperature and 10 +/- for the gas velocity and volume flow rate. The deviation was “Nil”.

4.4.2 Moisture Content

The stack gas moisture content was determined with the USEPA Method 4. At each site a measured volume of stack gas was bubbled through a series of chilled impingers each containing 100 ml of water and then drawn through a silica gel tube. The total change in volume of water in the impingers and the weight change of the silica gel were used to calculate the percentage moisture in the stack gas. The estimated accuracy is +/- 5 %. The oxygen concentrations were monitored in accordance with USEPA Method 3A. The estimated accuracy is +/- 5%. The deviation was “Nil”.

4.4.3 Oxygen

The oxygen concentrations were monitored with the USEPA Method 3A. In accordance with this method the sampled gas was withdrawn continuously from the gas stream and conveyed to an electrochemical O₂-Analyser. The estimated accuracy has been stated with +/-2%. The O₂-Analyser was on-site were calibrated twice at each run – before and after sampling.



The D/F sampling equipment

4.5 Determination of the Mass Concentration of PCDDs/PCDFs

The absorbent material, XAD-2 resin and the filter, were spiked prior to sampling with isotopically (¹³C₁₂) labeled PCDDs/PCDFs surrogate standards. In the laboratory PCDDs/PCDFs recovery standards were added to the sample components. The filter, resin and impinger were extracted with organic solvents and the extract purified by chemical treatment and solid phase chromatographic techniques.

The measurement of the PCDDs/PCDFs was performed using high resolution gas chromatography/high resolution electron impact mass spectrometer (HRGC/HRMS) in accordance with USEPA Method 1613A. The analytes are separated by the GC and detected by a high-resolution mass spectrometer.

5 Results and Discussion

For the test trial, the following principals were been followed strictly:

- For each of the three test runs the sampling of the stack gases started only after the control room of the kiln confirmed that the standard operating condition of the kiln were normal.
- In addition to the general QC procedures, the QC procedures specific to the USEPA 23 sampling method for dioxins and furans were followed strictly.
- Analyses for all parameters were performed strictly in accordance with the specified USEPA methods.

5.1 Condition of the Test trials

| | |
|-----------------------|--|
| Run 1 | 21st November 2004 |
| Operating conditions: | Normal Run – Baseline Compound Mode |
| Sampling time: | 6:19 hours |
| Sample Volume: | 6.893 m ³ |
| AFR feeding rate: | No AFR feeding – The cement kiln runs under normal condition |
| Run 2 | 22nd November 2004 |
| Operating conditions: | AFR Run 1 - Compound Mode |
| Sampling time: | 6:37 hours |
| Sample Volume: | 7.461 m ³ |
| AFR feeding rate: | 1. 75 tons/hour |
| Run 3 | 23rd November 2004 |
| Operating conditions: | AFR Run 2 - Compound Mode |
| Sampling time: | 7:45 hours |
| Sample Volume: | 5.521 m ³ |
| AFR feeding rate: | 3.5 tons/hour |

5.2 Standard Operating Parameters

The standard parameters measured during the cement process were continuously and automatically counted and collected from various sampling points in the cement plant and the control room. These data were collected during all stages of the test trial (Annex 2).

5.2.1 Economical advantages

Under normal conditions for the production of clinker in the kiln, the demand of fossil fuel is about 25 tons of coal per hour (7 tph main burner, 12 tph SLC, 6 tph ILC) – corresponding to 156,000 MJ. This amount of energy could be reduced during co-processing of the pet food as AFR.

During run 2, with a feeding rate of 3.5 tons pet food /hour the feeding rate of the coal could be reduced from 25 tons per hour to 22.7 tons per hour - – this is a reduction of 9.2%. The energy for the production of clinker has been replaced by the pet food. The feeding rate of 3.5 tons pet food/hour is equal to about 16.100 MJ.

5.3 Analytical samples for Future Reference

Representative samples of each stage (fired fuel, kiln feed, clinker, filter dust and pet food) were collected and stored in special containers and will kept for a period of at least 6 months for future references. These samples were collected according to the normal sampling procedure at every hour.

5.4 Problems with the CO-concentration during Run 3

For Run 2 all the parameters were robust through the whole period of the test trial. Problems occurred only within Run 3, after the feeding rate has been doubled - from 1.75 tons per hour to 3.5 tons pet food per hour. After the feeding rate has reached the value of 3.5 tons/hour and the parameters of the kiln stabilized, the PCDFs/PCDFs sampling stated. Approximately 30 Minutes later, the raw mill stopped working. At this stage sampling was been stopped.

After the restart of the raw mill and the stabilization of the kiln, the stack gas sampling continued. At that point, the CO rate in the kiln increased from 0 to 0.25 % CO. The operator of the kiln tried to reduce the CO concentration in the kiln by increasing the temperature in the kiln.



The control room of the cement plant

Due to the increased CO concentration in the kiln the stack gas sampling was interrupted twice.

Only after the fan was made to pull more gas, thus increasing the available oxygen the CO concentration went back to normal. The PCDDs/PCDFs sampling could be finished without further interruptions. These interruptions are explaining the lower sample volume of run 3 with 5.521 m³ stack gas in 7:45 hours compared to the sample volume of run 2 with 7.461 m³ stack gas in 6:37 hours.

5.5 The combined Condenser – Holding Time of the Spiked Condenser

The combined condenser is filled with 40 grams of the XAD-2 resin for the absorption of the dioxins and furans. The filter and the absorbent material were spiked prior to sampling with isotopically ¹³C₁₂ labeled PCDDs/PCDFs surrogate standards. For the test trial the combined condensers had been prepared in the Laboratory of the National Measurement Institute of Australia in accordance with the US EAP Method 23A.

The USEPA Method 23A does not stipulate a holding time for spiked condenser. The prepared condenser has to be kept in the dark and under refrigeration until use. The USEPA Method 1613A (for the analysis of dioxins and furans in soils, water and tissues) mentioned a holding time for spiked traps in the dark and storage temperatures at 0 - 4 °C for up to one year.

5.6 Results of the PCDDs/PCDFs Analysis¹¹

The PCDDs/PCDFs concentrations in the stack gas of the three test trials are summarized in Table 2. (Details see Annex 3):

Table 2

| Date | Run | I-TEQ (NATO) – Concentration ¹² PCDDs/PCDFs in ng/Sm ³ |
|----------|----------------------|---|
| 21. Nov. | Run1 (Compound Mode) | 0.00038 |
| 22. Nov. | AFR 1 (1.75 t/h) | 0,0012 |
| 23. Nov. | AFR 2 (3.5 t/h) | 0,0013 |

The toxic equivalent (TEQ) for each PCDD/PCDF congeners was calculated using NATO international toxic equivalency factors (TEFs).

¹¹ All the samples of the test trial were analyzed by the Laboratory of the National Measurement Institute of Australia.

¹² Sm³ = Gas volume in dry cubic meters at standard temperature and pressure (0°C and 101.1 kPa.)

For weighting the concentrations of the 17 PCDDs/PCDFs congeners with the toxicity, the toxicity equivalent factor (TEFs) established by the NATO/CCMS group (= I-TEFs) is reported. When calculating the TEQ, congeners that were below the detection limit were assigned a concentration of zero in agreement with the USEPA Method 1613 A, where a detection limit of 0.005 ng per congener was used. The non-detectable congeners are being ignored when calculating the TEQ.

For all three test trials the concentrations of the PCDDs/PCDFs were normalized to standard conditions, which are 273 K, 101.1 kPa. The O₂ concentrations have been recalculated to 10 % O₂ at standard temperatures. The estimated accuracy for the determination of PCDDs and PCDFs in stationary source emissions is +/- 25 %.

Run 2 shows higher concentration of the congeners by a factor of 10 compared to run 1. On the other hand, run 3 has nearly the same concentration of congeners as run 2.

All three test results are far below the international recommend standard of 0.1 ng PCDDs/PCDFs / I-TEQ/Sm₃.

6 Conclusions

The test results of the stack samples of this test trial, including those runs with elevated input of chlorides, were all far below the 0.1 ng TEQ/Sm³, which is the limit value in the European legislation for hazardous waste incineration plants (Council Directive 2000/76/EC). It is also much lower than the average concentration of about 0.02 ng I-TEQ/Sm³ measured among German cement kilns (see again Table 1).

All stack gas samplings were performed in full compliance with the USEPA Methods as well as with the European Standard EN1948-2.

The test confirms what has been found in numerous tests conducted in Europe and Australia – that the use of wastes in cement kilns can comply with strict limits on dioxin and furan emissions.

Furthermore, fossil energy was saved, as seen in the calculation of chapter 5.2.1.

Annex

- Annex 1: Analytical report of the Pet Food (CRL Environmental Cooperation)
- Annex 2: Cement standard operating parameters
- Annex 3: Analytical result from the Dioxin/Furan Monitoring (AirLabs/Australia)