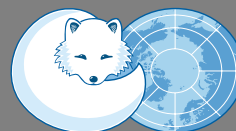




ARCTIC CONTAMINANTS
ACTION PROGRAM



ARCTIC COUNCIL

FEASIBILITY STUDY FOR DIOXIN MITIGATION

AND OTHER ENVIRONMENTAL PILOT MEASURES
AT THE VORKUTA CEMENT PLANT IN THE KOMI REPUBLIC

Feasibility study for dioxin mitigation and other environmental pilot measures at the Vorkuta Cement Plant in the Komi Republic

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1 Performed activities

This assignment is Phase 2 of the Feasibility Study for dioxin mitigation and other environmental pilot measures at the Vorkuta Cement Plant (VCP) in the Komi Republic (in the Russian Federation). As part of Phase 1, in 2012 a technical evaluation of various measures for reduction of emission of dioxins/furans (PCDD/PDCT) and dust from the plant, as well as a business plan for implementation of the measures, were undertaken. Since the evaluation in 2012, major changes have taken place at the VCP, as described in this report.

The following activities have been undertaken as part of this Phase 2 assignment:

- › Update of technical and environmental part of the phase 1 report describing implemented changes in the plant. This is described in chapter 2 of this report. The chapter includes a description of the current situation as regards emissions of pollutants from the plant, based on a report from a parallel assignment implemented by the Polar Foundation (2016).
- › Description of further measures for pollution control and environmental improvements at the plant. Described in section 2.5.
- › Description of the current economic situation of the plant. Due to a difficult economic situation, a full business plan for implementation of measures has not been undertaken. The situation is described in chapter 3
- › Recommendations regarding the need for a cooling tower and monitoring of PCDD/PCDF emission. Described in section 2.5.
- › Supervision of measurements of dioxins/furans and other pollutants. The supervision is described in Appendix 1 on the basis of the inception report of the project.
- › Comments to the obtained results as reported in the parallel assignment of Polar Foundation. The comments have been provided in separate notes, e-mails, and teleconferences. The comments were extended to include comments to analytical results undertaken by Umeå University in Sweden. Summarised in Appendix 1.3.

- › Development of action plan with regard to PCDD/PCDF and dust emission from the VCP and for the use of alternative fuel. Described in chapter 5.
- › General recommendations on using the kiln for waste incineration. A detailed description of general recommendations is included in Appendix 2 to this report, and the main recommendations are summarised in chapter 4.
- › Preparation of fact sheet on best practice for dioxin monitoring/control in EU countries. Included in Appendix 3.
- › Review of Barents hot spot list. Reported in separate note of January 2015 and included as Appendix 4.
- › Participation in seminar/workshop in Syktyvkar August 2014 with presentations. Reported in the seminar minutes and the Inception Report.
- › Participation in 2-days wrap-up seminar in Moscow with presentation of draft Phase 2 results, November 2015. Reported in the seminar minutes.

2 Update of technical and environmental parts of Phase I report

2.1 Introduction

A detailed description of the history of the VCP, and the technical process at the plant, is available in the Phase 1 report. The description below focuses on changes since the Phase 1 evaluation was carried out in 2012.

A significant part of the measures proposed in the phase I report has now been implemented by the VCP, using own funds.

2.2 Changes in pollution controls at the VCP

The 2 large kilns (kiln 2 and 3) at VCP have a production capacity of approx. 110.000 tons per year per kiln. Due to the reduced demand for cement, only one kiln has in recent years been in operation and only part time.

Installation of ESP

Vorkuta Cement has in 1990 purchased three Electrostatic Precipitators (ESPs) for cleaning of exhaust gas after the kilns; one ESP for each kiln. The ESP's were during Phase 1 partly installed and the Phase 1 report listed equipment needed for final installation.

Each ESP for kiln 2 & 3 has the following specification:

- › 1 Chamber, 4 electrical fields.
- › Each electrical field H x B x L: 8,75m x 9,2m x 4m, Duct width 350 mm, 2 pyramid bottom hoppers with air sluice.
- › High voltage power supply: voltage 70 kV, current 1000 mA
- › Each chamber, cross section area 80.5 m²
- › Each chamber, total collecting area 7360 m²

In 2013, the ESP connected to Kiln 2 was installed and connected to the main stack. The costs were covered by the plant's own funds.

Kiln 2 is the only kiln operating at the moment, and with the current market situation it is not foreseen that the more kilns should be operating in the near future. The plant, consequently have no current plans for final installation of the other ESPs. In case the production would increase significantly the coming years, it would be necessary to invest in the final installation of one more ESP.

Dust recycling

The dust collected in the ESP is transported to a common silo and recycled as raw material back into the cement process. During phase 1 of the project, the dust collected in the flue gas was analysed and the analysis indicated that the dust was suitable for recycling. By the recycling of the dust, the need for raw materials has been reduced. Before installation of the ESP the dust formation was approximately 47 kg/tonne cement produced, and the recycling consequently reduce the raw material consumption by approximately 5%.

2.3 Emission of pollutants

2.3.1 Dust emission and dust recycling

VCP was included in the Barents Environmental Hot Spot list due to high emission of dust. In 2003, the reported emission of dust was 8,400 t/year (Akvaplan-niva, 2013).

According to the Phase 1 report, the emission of inorganic dust from the VCP peaked at an emission of nearly 13,000 tonnes of dust in 2007 and 2008. As consequence of the decrease in production due to the economic crisis, the emissions decreased dramatically the following years and reached 1,300 tonnes in 2010.

The emission in 2012 was roughly estimated in the Phase 1 report at approximately 5,300 t/year assuming an emission rate of 6,000-24,000 ng/Nm³. The emission per tonne of cement was estimated at approximately 47 kg/tonne.

Subsequently, the emission per tonne was measured in 2013, before installation of the ESP, at 76 kg/tonne cement.

According to the information from the Polar Foundation (2016) report, the installation of the ESP has been highly efficient in reducing the dust emission from the plant.

According to available data from 2012 and 2014, shown in the table below, the efficiency of the ESP in reducing the emissions was between 97 and 99%. This is within the range reported from European cement plants equipped with ESP (BREF, 2013). The dust emission ranges for European cement kilns are in the European BREF (2013) indicated at 0.27-227 mg/Nm³ corresponding to 0.6 - 522 g/tonne clinker. The emission after the ESP in the VCP is measured at 335-662 mg/m³ (not indicated if this is normalised m³) which is higher than reported from European cements plants.

The production output when kiln 2 is in operation is measured at approximately 17 t/h. The calculated dust emission of 30 kg/h in May 2014 corresponds to an emission factor of approximately 2 kg/tonne cement; which is still quite high as compared to the ranges in European cement kilns. With a total production in 2014 of 120,000 tonnes, the total emission in 2014 can be estimated at approximately 240 tonnes. If it is assumed that about 50 kg dust is captured per tonne cement, the total amount captured can however be estimated at 6000 tonnes in 2014.

According to the information obtained from the VCP, some activities have been undertaken in order to improve the efficiency of the ESP, but the results obtained are not documented with actual measurements.

According to the obtained information, the emission of dust from the plant is within the limits set by the authorities (Rospirodnadzor for Komi Republic) in the permit for the plant.

Table 1 Emission of dust before and after installation of the electrostatic precipitator (ESP) (based on Polar Foundation 2016)

Data for sampling	August, 14 2013	August,26 2013	November, 13 2013		May 26, 2014	
ESP installed	No	Yes	Yes	Yes	Yes	Yes
Sampling site		After ESP	Before ESP	After ESP	Before ESP	After ESP
Emission, g/s	355	14	460	14	627	8
Emission, kg/h	1.277	52		49		30
Emission, mg/m ³ *	11381	335	-	662	17412	397
Emission, kg/tonne ce- ment produced**	76	3		3		2

* Not indicated if this volume has been normalised.

** Output of cement is 16.7 t/h.

2.3.2 Emission of dioxins (PCDD/PCDF)

Emission in 2004

Two measurements of dioxin emission were undertaken by Institute for Hygiene, toxicology and Occupational Pathology, RF Ministry of Health, August 2004 (CIP, 2005) as part of Phase 1 of the ACAP PCDD/PCDF project (not to be confused with Phase 1 of this project). The measurements showed an emission of 0.5-0.6 ng TEQ/Nm³ which was close to the default emission factors of cement plants using wet technology given in the UNEP PCDD/PCDF Toolkit. The total emission from the VCP was in the ACAP PCDD/PCDF study Phase 1 report estimated at 0.735 g TEQ/year in 2001 based on a production of 147,000 tonnes cement. This corresponded to 18% of the total PCDD/PCDF emissions from the Republic of Komi (CIP, 2005). The VCP was the largest industrial point source in the Komi Republic and among the five largest in the region. The significant contribution of the VCP to the total PCDD/PCDF emissions in the Republic of Komi and the region, as well as

the location in the Arctic, was the background for further investigating possible measures for reducing the emissions from the plant.

Emission in 2014

According to the result of the measurement campaign in September 2014, i.e. after installation of the ESP, the emission in 2014 was considerably lower than the rates measures in 2004. In six measurements the concentration ranged from 0.017 to 0.116 ng I-TEQ/Nm³ with an average of 0.05 ng TEQ/Nm³ as shown in the table below. The levels were in general lower in the situations where complementary fuel was used, but the differences are within the variability and not significant (e.g. at a 90% significance level). Consequently, it is possible to use the average value as the best estimate. Based on the measurements, an average emission factor of 276 ng I-TEQ/tonne cement can be estimated. Using this emission factor and a total production output of 120,000 tonnes in 2014, the total PCDD/PCDF emission can be estimated at 0.03 g I-TEQ/year.

Table 2 Results of gas analysis PCDD/PCDF by Typhoon and Umeå University (Polar Foundation, 2016) normalised to 10% O₂ *

#	Sampling date	Fuel used (comp. = complementary fuel)	Concentration ng I-TEQ/Nm ³		Estimated mission factor ng I-TEQ/tonne cement	
			As reported by Typhoon	As reported by Umeå University	Based on Typhoon	Based on Umeå University
1	04.09.14	Coal	0.078	-	438	**
2	04.09.14	Coal	0.116	-	655	
4	04.09.14	Coal	0.028	-	159	
5	04.09.14	Coal	-	0.024		
7	05.09.14	Coal + comp.	0.023		133	
8	05.09.14	Coal + comp.	0.017		101	
9	06.09.14	Coal + comp.	0.030	-	170	
10	06.09.14	Coal + comp.	-	0.031		
		Average	0.049		276	

* Normalisation to 10% O₂ is in accordance with the Directive 2000/76/EC as concerns cement plants co-processing waste. ** Data not provided

The measured concentration of PCDD/PCDF in the dust captured by the ESP ranged from 0.73 to 1.12 pg I-TEQ/g dust (pg/g = µg/t) (see table below). With approximately 6000 tonnes captured in 2014, and an average concentration of 0.93 pg I-TEQ/g dust, the total content of the dust can be estimated at 0.11 g I-TEQ; corresponding to approximately 15% of the 2004 emission. The reduced emission can as expected not be explained by the installation of the ESP. By comparing to the estimated emission of 0.03 g I-TEQ in 2014, the retention efficiency of the ESP can be estimated at approximately 79%. As expected, this is well below the retention efficiency for dust.

Table 3 Comparison of results of dust analysis PCDD/PCDF by Typhoon and Umeå University

#	Sampling date	Fuel used (comp. = complementary fuel)	Concentration (pg I-TEQ/g dust)		Emission factor (ng T-TEQ/tonne cement)	
			As reported by Typhoon	As reported by Umeå Uni.	Based on Typhoon	Based on Umeå University
6	04-05.09.14	Coal	1.12	0.9*		
11	06-07.09.14	Coal + comp	0.73	0.3*		

* Indicated as 0.07 and 0.03 pg I-TEQ/g dust by the Polar Foundation, 2016, but here calculated from original data.

The congener specific contribution to the total I-TEQ was fairly stable among the samples of air emission with the highest contribution from 2,3,7,8-penta CDF and 1,2,3,4,6,7.hepta-CDF which, according to Danish experts, is common for this type of source.

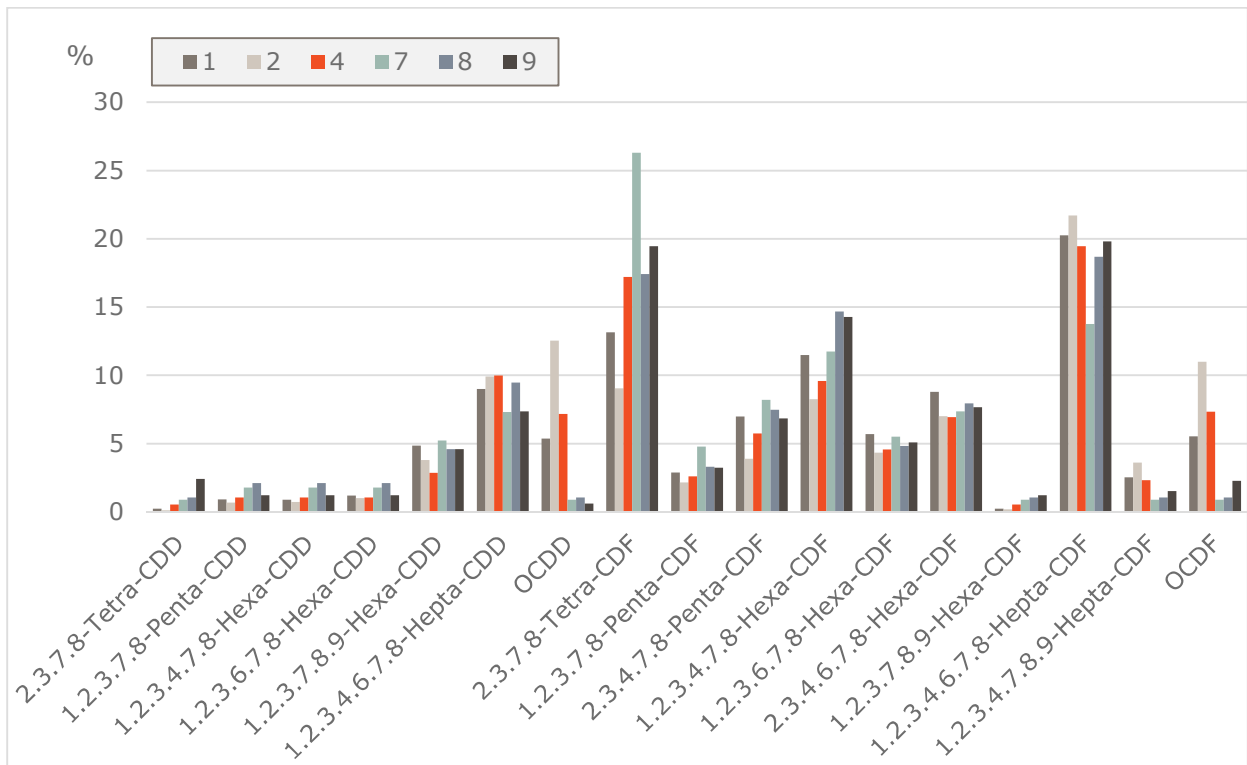


Figure 1 Congener contribution to total I-TEQ in the emission samples

2.3.3 Emission of other pollutants

Heavy metals

The results of measurements of heavy metals in the dust captured from the ESP in the situation with and without the addition of alternative fuel is shown in the table below. As only one sample was analysed for each situation, the variance cannot be

determined and the differences between the two datasets may be due to variation and not reflect actual general differences between the two situations. As an example, the reduction of the manganese concentration by 50% when 5% complementary fuels are used cannot be attributed to the use of alternative fuels. For none of the elements very pronounced increases are seen when alternative fuels are used. The total quantities captured in the dust illustrates the efficiency of the ESP in reducing the releases of the measured heavy metals from the plant to the environment. Notably, the releases of lead in 2014 was reduced by nearly 3 tonnes as compared with a situation where the ESP was not installed. When recycling the dust, the non-volatile and semi-volatile (e.g. Pb, Cd, Sb) heavy metals to a high degree or almost completely ultimately ends up in the clinker (BREF, 2013).

For volatile elements, in particular mercury, the majority of mercury fed into the process ultimately is released as elemental mercury to the environment. For mercury, recycling of the dust overall result in increases in the total releases.

The actual releases cannot be determined from the available data, as the concentration in the fine dust passing the ESP may be different from the concentration in the dust captured by the ESP. In general, the reduction efficiency of the ESP is lower for the semi-volatile heavy metals such as lead (Pb) and cadmium (Cd) than it is for dust. According to the guidance document on best available techniques for controlling emissions of heavy metals and their compounds from the source categories listed in Annex II to the Protocol on Heavy Metals, the retention efficiency of ESP (cold side) control devices is >90% for lead and cadmium, and 10-40% for mercury, whereas it is more than 99% for the dust (ECE, 2013). Based on this, the total emissions to the air in 2014 from the VCP (except for Tl and Hg) is likely not more than 10% of the total amounts in the dust as calculated in the table below.

Table 4 Results from quantitative chemical analysis of metal content in dust samples and resulting calculated annual release estimates

Sample #/ unit	Unit	Pb	Cd	Sb	As	Cr	Co	Cu	Mn	Ni	V	Tl	Hg
6 (coal)	mg/kg	368	0.36	<1.00	37.2	80.8	4.45	103	415	58.0	90.7	0.74	0.06
11 (coal and comp. fuel)	mg/kg	557	0.29	<1.00	59.3	76.8	6.93	106	242	63.2	92.1	0.63	0.15
Average	mg kg	463	0.325	<1.00	48.3	78.8	5.69	105	329	60.6	91.4	0.685	0.105
Approx. annual quantity in dust in 2014, *	kg/y	2,775	2.0	0	290	473	34	627	1971	364	548	4.1	0.6

* Calculated based on a production of 120,000 tonnes in 2014 and generation of 50 kg/tonne cement i.e. a total of 6,000 tonnes dust.

Black carbon (soot)

The measurements demonstrate that the content of soot (of this a major part is black carbon) in the dust after the ESP is 720 mg/ton dust with the use of coal and

2,008 mg/ton dust with addition of alternative fuel. With only two measurements, the differences cannot be considered significant.

With a dust emission of 2.5 kg/tonne cement (average of measurements after the ESP), a cement production of 120,000 t/year and soot content of 720 mg/tonne dust, the total soot emission can be estimated at 0.2 kg/year.

Black carbon emission from cement plants is in general not regarded a major environmental issue, and the European BREF document for the cement industry does not mention black carbon or soot emission at all.

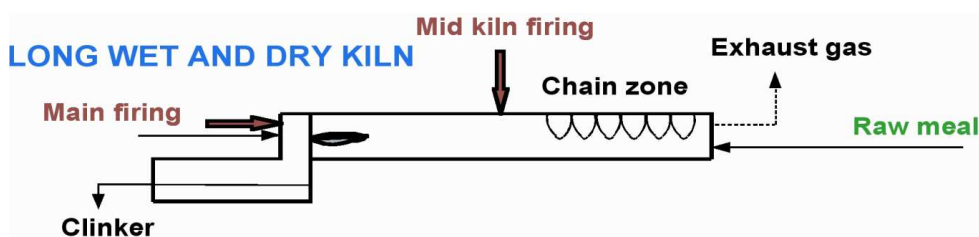
Cement production is not considered a major source of black carbon and is not specifically mentioned as significant sources in inventories of black carbon emissions in the Arctic (e.g. Quinn et al., 2011; NEA, 2014). Total emission of black carbon from the Arctic Nations in 2000 is estimated at 600,000 tonnes (Quinn et al., 2011). The emission of 0.2 kg/year from VCP is in this context insignificant and the plant cannot be considered a hot spot for black carbon emission.

2.4 Actual use of complementary fuels at the VCP

Tyres and railway sleepers are currently used as complementary fuel at the VCP at a thermal substitution rate of 5-10%. The fuel is introduced into the burning chamber at the lower end of the kiln where the burning dust coal is forced into the kiln. The fuel is not introduced into the kiln. The tyres are cut manually into two parts with an angle grinder. The cutting results in formation of heavy rubber fumes and the working environment conditions are not optimal. It is obvious that the use of alternative fuels, beyond the current test runs, would require improved pre-treatment and loading of the fuel.

During the sampling campaign in September 2014, the railway sleepers and tyres as alternative fuel were added every hour at a substitution rate not exceeding 5% (100 kg sleepers and 85 kg tires). The use of complementary fuel did not result in higher emissions of PCDD/PCDF.

The alternative fuel is introduced by the main burner chamber to the left in parallel with the coal main firing as shown in the figure below.



Due to high temperature and long residence time inside the kiln, complete burnout and no influence on dioxin formation can be expected. As mentioned in Annex 2, the situation would be much different if the tyres and sleepers would be fed together-

er with the raw meal. Organic components of the raw meal of waste fed with the meal may have a significant influence on the formation of PCDD/PCDF in the process.

According to the obtained information, the use of these complementary fuels in cement kilns is permitted and regulated by GOST R 55099 – 2012 “Efficient Use of Resources” – item 4.2.4.1. The use the abovementioned waste types as a complementary fuel does not require a special permit.

According to information from the director, the plant considers at the moment use of other complementary waste based fuels as described in section 0.

2.5 Suggested measures for further reduction of pollutants emissions from the VCP

2.5.1 Cooling tower

As the measurements of PCDD/PCDF have demonstrated that the emissions are below the limit values of the EU waste incineration directive for cement plants co-processing waste, it is recommended not to install a cooling tower.

Even though a cooling tower would be useful in further reducing the emissions and would be considered best available technique (BAT), it is in the current economic situation of the plant not recommended to work for an implementation of a cooling tower. The incentives for the plant in investment in equipment not required by the authorities is considered to be very low.

In case certain chlorine-containing waste types (e.g. car shredder fluff in the future) are used as complementary fuel, it is recommended to monitor the emission of PCDD/PCDF and re-evaluate the need for a cooling tower as further described in section 4.

2.5.2 Online monitoring of pollutants emissions and process parameters

The director of VCP has expressed an interest in extending the scope of the project, e.g. by investments in a system for continuous on-line monitoring of air pollutants. As continuous monitoring systems are recommend in various BAT documents for the cement industry, this opportunity has been assessed further.

Recommendation of the European BREF for cement production

According to the European reference document on Best Available Techniques (BAT) for the cement industry (BREF, 2013), in order to **control kiln processes**, continuous measurements are recommended for the following parameters:

- > pressure
- > temperature

- › O₂ content
- › NO_x
- › CO, and possibly when the SO_x concentration is high
- › SO₂ (it is a developing technique to optimise CO with NO_x and SO₂).

In order to accurately **quantify the emissions**, continuous measurements are recommended for the following parameters (these may need to be measured again if their levels can change after the point where they are measured to be used for control):

- › Exhaust volume (can be calculated but is regarded by some to be complicated)
- › Humidity (can be calculated but is regarded by some to be complicated)
- › Temperature
- › Dust
- › O₂
- › NO_x
- › SO₂, and
- › CO.

Regular periodic monitoring is appropriate for the following substances:

- › Metals and their compounds
- › TOC (total organic carbon)
- › HCl
- › HF
- › NH₃, and
- › PCDD/PCDF

If waste is used in cement kilns, often emissions of TOC and mercury, especially in the case of using sewage sludge, are monitored from the exhaust gas of cement kilns (in some cases continuously), additionally to the regular continuous measurements of dust, NO_x, SO₂ and CO emissions, that are carried out.

Both inlet and outlet parameters are used to fine-tune the production process. The fine-tuning of process and ESP on the basis of the online monitoring of these parameters contributes to a general reduction of the generation and emission of pollutants.

It is well-known that unstable conditions in the kiln, e.g. by start up and close down or changes in the fuel composition, result in higher emissions of pollutants. The current situation at the VCP, with changes in production output (manufacture of different products and cement qualities) and changes in fuel composition (with addition of complementary fuels) may result in higher emissions than could be obtained under stable conditions.

The advantages of an online monitoring systems would be:

- › Basis for more stable kiln conditions resulting in higher product quality and lower emissions

- › Better options for fine-tuning of ESP (influencing the emissions of dust, heavy metals, black carbon, etc.)
- › Generate data for reporting of pollutant emission to the authorities
- › Indication of major changes in emissions by use of alternative fuels.

Current monitoring on the VCP

Data on current monitoring has been requested from the VCP several times, but very limited data have been provided. Temperature and pressure are measured at certain measuring points, but details have not been provided.

Equipment on the market for online monitoring

Different equipment is on the market for online monitoring of various substances in gas inlets and outlets. The following is based on information from the Danish company FL Smidth which supplies the minerals and cement industries globally with everything from engineering, single machines and complete processing plants to monitoring equipment, maintenance, support services and operation of processing facilities. The company operates on the Russian market via Russian suppliers and brochures describing the equipment in Russian have been submitted to the director of the VCP. Prices indicated in this section are estimated prices (excl. VAT) for supplying the equipment in Russia. Prices are without installation of the equipment and training, which are considered small as compared to the prices of equipment.

The equipment for online monitoring supplied by FL Smidth consists of three parts:

- › Equipment for cement kiln online inlet gas analysis
- › Equipment for online analysis of stack emission
- › Reporting system

Inlet gas analysis - Kiln inlet gas analysis systems deliver essential data on components of the kiln inlet gas. By the use of inlet gas analysis it is possible to regulate the O₂ and CO produced in the processes at source, in order to optimise combustion and reduce the amount of pollutant generated. By use of online monitoring, it is possible to reduce the energy consumption and reduce the downtime costs. According to the provider, the payback of an on-line kiln inlet gas analysis system is often less than 200 days (but may be significant higher with the relative small production output at the VCP).

The components measured are typically O₂, CO and NO_x, whilst some plants also measure SO₂ and CH₄. In connection with implementation, there will be a need for both air for cleaning the probe and cold water for cooling of the probe. Furthermore, there is a need for space for a control panel either in a supplied cabinet (add-in) or in a temperature-stable and dust-free room.

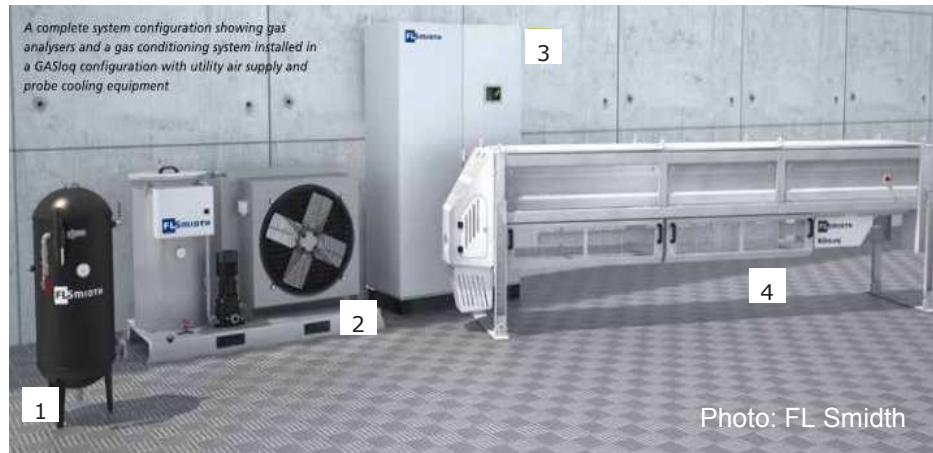


Figure 2 Example of system for cement kiln inlet gas analysis. System with utility air supply (1), water panel (2), gas analysers cabinet and (3) and probe system (4)

Stack emission analysis - The emission system configuration will be dependent on the legal requirements, production permits and plant layout. Most systems are installed in the stack, and the emission application typically requires the utilization of both extractive and *In Situ* systems. The various analysers are operated according to differently principles and require calibration according to specific procedures and time frames.

For a cement plant not co-processing waste typically O₂, CO, NO_x og SO₂ together with the pressure and temperature are measured, as indicated above from the BREF document. The substances are measured continually in the flue gas. To this end is used an extractive analysis system, which extract a gas flow from the main outlet.

This could be combined with a probe for monitoring of dust and flow. The latter would be used for calculating total emission and may be omitted.

For plants co-processing waste of variant composition, measurements of TOC and mercury may also be relevant. As long as the VCP co-process tyres, sleepers and possibly waste oil, it is not considered necessary to add TOC and mercury measurements.



Figure 3 Example of online monitoring system for stack emission

Reporting system - Online reporting data processing and reporting system allows employees with responsibility for the environment to extract up-to-date reports and monitor the system where and when they want. In the system provided for the system described above, all data is securely stored on the equipment provider's servers through the Internet, who also ensure automatic backup. The system removes, according to the provider, the need for operation and maintenance of local server solutions, resulting in a flexible, more secure solution than traditional analysis systems provide.

The availability and possible costs of other data processing systems, without the on-line data management by the equipment provider, has not been assessed.

Indicative costs of online monitoring systems

Indicative prices for the different parts of the system is shown below. Excluding the add-on options, the total costs are approximately 243,000 € based on list prices from FL Smidth considered to be indicative for the Russian market.

To this should be added the possible costs of installation of the equipment and training of staff of the VCP in using the monitoring system. Based on experience with installation in other plants, total time for a technician from the supplier for installation, training of staff and travelling is estimated at 14 man-days (5 for input control, 5 for output control, 2 for reporting system, 2 for travel) of 1066 €/day = 14.900 €. With travel costs, the total for these services may be estimated at approximately 16,000 €.

Total costs of one annual maintenance of the equipment by a technician from the equipment supplier is roughly estimated at 5,300 €/year.

If a solution with a reporting system managed by the equipment supplier is chosen, some annual costs for this service should be added.

It has not been further assessed if less expensive equipment may be available from other suppliers on the Russian market.

It should be noted that the equipment for online monitoring system would be the same for a large cement plant with an annual output of several million tonnes cement, and the costs would be relative high for a plant with a relative small output of about 100,000 t/year.

Table 5 Indicative price of equipment for online monitoring of inlet and outlet gases (obtained in 2015)

	Equipment	Indicative price (excl. VAT) in EUR
Inlet gas analyses	Probe and gas analysis system for measurement of O ₂ , CO, NO _x , SO ₂	117,000
	Add-on cabinet, incl. gas detection	17,000
Outlet gas analyses	Probes and gas analysis system for CO, O ₂ , NO _x and SO ₂	60,000
	Dust, incl. "low temperature" protection	14,000
	Flow, incl. "low temperature" protection	19,000
	Add-on cabinet, incl. gas detection	17,000
Reporting system	Reporting system (excl. maintenance)	33,000
Total excl. add-on		243,000
Total incl. add-on		277,000
Installation of entire system	14 man-days of technician incl. travel	16,000
Total incl installation excl. add-on cabinet		259,000
Total incl. installation add-on cabinet		293,000

2.5.3 Improvement of electrostatic precipitator (ESP)

Kiln 2 is the only kiln operating at the moment, and with the current market situation, it is not foreseen that the more kilns should be operating in the nearest future. The plant consequently have no current plans for final installation of the other ESPs.

The efficiency of a precipitator depends on the operating conditions, gas flow, temperature, humidity, particle size and chemical composition and electrical resistance of dust. Further, the efficiency depends on the design of the precipitator i.e. size of precipitator, type of collecting plates, type of discharge electrodes, gas distribution, high voltage power supply and power control system and strategy.

As assessed in the phase 1 report of the project (COWI, 2013), based on the ESP technical data and experience from other plants, the capacity of the ESP, if connected to one kiln only, is high enough to ensure reaching a dust concentration in the flue gas after the ESP of 10 mg/Nm³ (0.9 kg/h).

According to the draft report prepared by Polar Foundation, the measured dust emission after ESP in 2014 was 398 mg/m³ (29.6 kg/h).

The limit value of EU Directive 2000/76/EC on the incineration of waste is 30 mg/Nm³ i.e. 1/10 of the actual emissions at the VCP after the ESP.

According to the Russian BAT (2015)¹ document for the cement industry, the retention efficiency of ESP for all dust is 95-99% (p. 179). The retention efficiency of the ESP at the VCP was according to the report of Polar Foundation (2016) measured at 97% (Nov 12 2013) and 99% (May 26 2014), which is in the range of possible retention indicated in the Russian BAT document.

According to the Russian BAT document, in general, the maximum dust emissions from cement kilns are observed in old cement plants with the wet process, equipped with ESPs of the vertical type, and working for a long time without modernization and necessary maintenance. With timely implementation of necessary organizational and technical measures, the average level of dust emissions from cement kilns at these plants should not exceed 150-250 mg/Nm³. For advanced cement plants with dry process cement kilns, dust generally does not exceed 50-100 mg/Nm³ (p 178) (relatively high as compared with European standard). The document makes reference to a number of Russian cement plants with lower emissions. The measured levels in the VCP are relatively high as compared with the 150-250 mg/Nm³ indicated in the Russian BAT.

The data on emission concentrations indicates that the efficiency of the ESP may be improved, even though the emissions today is within the limits accepted by the authorities, and below the retention efficiency indicated in the Russian BAT document.

According to the director of the VCP, within the last years some improvements of the ESP have been obtained by fine-tuning of the filter. This has been undertaken by staff of the plant.

The manufacturer of the ESP is still operating on the Russian market, and it may be possible to optimise the efficiency of the filter by assistance of a technician from the company. An online monitoring system for dust emission would significantly improve the possibilities of fine-tuning of the ESP, and thereby for reducing the emission of most pollutants. It is suggested to await the installation of a monitoring systems before further fine-tuning of the ESP is implemented, and the possible costs of assistance from the ESP equipment provider has not been assessed.

The costs of fine-tuning of the ESP has not been estimated, as it can only be estimated after a detailed inspection of the installed ESP by an ESP specialist.

¹ ФЕДЕРАЛЬНОЕ АГЕНТСТВО ПО ТЕХНИЧЕСКОМУ РЕГУЛИРОВАНИЮ И МЕТРОЛОГИИ. ИТС 6—2015 ПРОИЗВОДСТВО ЦЕМЕНТА. БЮРО НАИЛУЧШИХ ДОСТУПНЫХ ТЕХНОЛОГИЙ



Figure 4 Dust collection from the ESP at the VCP

2.5.4 Implementation of environmental management system

The phase 1 report suggested among other measures to implement an environmental management system. According to obtained information, it is common in Russia that cement plants have environment management plants in accordance with ISO 14001, partly because this is required by some of the customers.

As mentioned in the European BREF and the Russian BAT document, an environmental management system (EMS) is a technique allowing operators of installations to address environmental issues in a systematic and demonstrable way. EMSs are most effective and efficient where they form an inherent part of the overall management and operation of an installation. An EMS focuses the attention of the operator on the environmental performance of the installation; in particular through the application of clear operating procedures for both normal and other than normal operating conditions, and by setting out the associated lines of responsibility. All effective EMSs incorporate the concept of continuous improvement, meaning that environmental management is an ongoing process, not a project which eventually comes to an end.

When developing and implementing an EMS, it is common to have external assistance in setting up the system and for training of the staff. The service may be provided with an international consultant or a Russian consultant. Based on experience with development and implementation of EMSs in Eastern Europe, it is estimated that implementation of the system using international experts would cost approximately 100,000 €. To this should be added the salary costs of the VCPs

own staff for development and training. The costs using local experts have not been estimated, but is expected to be lower than the costs indicated above.

The Director of the plant has not expressed any interest in investment in an EMS. Besides, Nefco has expressed that investments in hardware would have higher priority.

2.6 Implementation of suggested measures

The suggested measures with online monitoring systems can be implemented within a few months after the finalisation of a tendering process.

2.7 Benefits to other cement plants in Russia

According to the Typhoon sampling team, measurements of PCDD/PCDF is common among the cement plants in Russia; in particular on plants owned by foreign cement companies with own internal guidelines for emission reduction.

VCP is a small cement plant representing about 0.2% of the total cement production in Russia and the ten companies with the highest cement production in Russia each have a production of more than twenty times the production output of the VCP (total 68 million tonnes in 2014, Russian BAT p 22).

The VCP is an old, worn down facility and an upgrade would rather aim at bringing the facility to the same level as other facilities, than implement BAT technologies, which could serve as pilot examples for other cement plants in Russia.

3 Update of financial part of phase I report

Over the last two years numerous attempts has been done by the Consultant to collect information to be used for updating the financial part of the phase 1 report. Missions to Vorkuta for collection of data from the VCP has been arranged several times, but they have all been cancelled because the VCP had no time for meeting with the Consultant and no time for compiling the necessary information for an updated business plan.

The cement production industry is currently suffering from low demand of its products due to economic crisis in the Russian Federation. Besides this, the prices for cement are going down while the general inflation take place and prices for energy, rail transport tariffs and materials (incl. packaging) are going up. All these circumstances place cement plants in a difficult situation. Only the biggest cement holdings with foreign participation that are located in the European part of the country (where the market is wider) could survive under these conditions, albeit also with difficulties.

The nearest cement production plant to Vorkuta, located in Arkhangelsk was closed down and some part of its production equipment was dismantled.

Cement production at the VCP has decreased to 70,000 t in 2015 compared to 120,000 t in 2014 and 160,000 t in 2013. No specific data has been obtained on the production in 2016 but according to the Director (telephone interview September, 2016) the production level is still very low. The decrease of production was also reflected in some decrease of the company staff.

In order to diversify its production, the VCP management has introduced production of a special kind of sealing cement for the oil & gas industry operating in Arctic conditions, as well as a special output for road construction at a possible capacity of 20,000 t annually. Data on the actual production volume has not been obtained. These products are currently in low demand, but if the projected investments in the Russian Arctic take place, they would probably be of high value according to the director of the VCP.

Due to this situation, the management of VCP pay high attention to cost-decreasing measures. In the year of 2014, the management introduced application of alternative fuels that provided a possibility to decrease the production costs.

There is also growing interest from other businesses to dispose of waste by combustion at the VCP. For instance in 2015, there was a request from Syktyvkar for utilization of car shredder waste by combustion, and there are also discussions with a company from Usinsk concerning burning of oil-containing waste from oil-drilling. This waste is utilized in other parts of Komi, but due to lack of related infrastructure in the Vorkuta area, there is a local need for destruction of the waste.

By the late 2015 there was a threat that the company would be declared as a bankrupt, but it did not happen.

According to a telephone interview with the director of the plant September 2016, VCP spent (in total) about RUR 60 million (~USD 1 million) on the installation of the ESP and it is working right now. VCP has no requirements from environmental authorities for further reduction of dust or other pollutants. The director does not see any needs to spend more of the company's own funds for further flue gas control under the current circumstances with a difficult market situation.

The director expressed that the company is not interested in loans, but grants (without any loans) would be considered.

4 Use of alternative fuels based on waste

One of tasks of the assignment is to provide general recommendations on the use of alternative fuels and hazardous waste (incl. pesticides) in cement kilns and general recommendations on structural changes required for introduction of new fuels in the VCP such as fuel acceptance area, storage, transportation, feeding, etc.

Recommendations on the use of waste for waste incineration at the VCP is included in Appendix 2 with a short summary here.

4.1 International and Russian BAT guidelines

International standards

The guidelines of the Basel Conventions and the Stockholm Convention for co-combustion of hazardous waste in cement plants are available in Russian. The recommendations provided in Appendix 2 of this report is in accordance with the guidelines.

Russian BAT document

A Russian BAT document for co-processing of waste in the cement industry has been developed and published by the Federal Agency on Technical Regulating and Metrology as ITS 6–2015 Cement Production.

With regard to PCDD/PCDF emission, the Russian BAT makes reference to the European BREF. The European BREF includes a description of methods to prevent formation and emission of PCDD/PCDF, including quick cooling of kiln exhaust gases to lower than 200 °C in long wet and long dry kilns without preheating. However, the part of the EU BAT document which describes the prevention of formation and emission of PCDD/PCDF, has not been implemented in the Russian BAT standard. The Russian BAT document mainly focuses on how the fuels are effectively used and on energy efficiency. As concerns prevention of PCDD/PCDF formation, the Russian BAT document mentions a short residence time of the flue gases in the temperature range conducive to synthesis of polychlorinated dibenzodioxins and furans.

The Russian BAT standard clearly indicates that for control of the emission of mercury and other volatile metals, it will be needed to limit their entry into the kiln by preventing mercury input to the waste.

The director of the VCP indicated at a meeting with the Consultant that from his point of view, the most important information that could be provided from the project would be information on where different types of waste should be fed into the kiln. For this purpose, he has suggested to provide a layout of the kiln with indication of the temperature regime and flow conditions and openings for feeding of raw materials and fuel. The consultant will further assess to what extent it would be possible and meaningful to provide such specific information within the scope of the project. If very process specific information on feeding of waste should be prioritised, the consequence would be that less priority is given to general information on other aspects such as acceptance, storage, and transportation. We would kindly ask for NEFCOs consideration regarding how much priority should be given to the questions regarding the feeding points of different alternative fuels.

The Rosprirodnadzor for Komi Republic expressed interest in models for estimation of changes in air emissions as result of changes in the fuel composition. Such models do to the knowledge of the consultant not exist.

4.2 Specific recommendations regarding the use of alternative fuels based on waste at the VCP

General guidelines for the use of waste as complementary fuel in cement plants are described in Appendix 2.

The procedures applied for the current use of tyres and sleepers in the VCP is very far from the procedures proposed if best available techniques should be applied. Procedures and equipment for the management of the waste should be developed from scratch. According to the information obtained from the Director, there is no plans for development of a full systems for use of complementary fuels, rather some intentions to continue at the current level with low-tech feed of 5-10% complementary fuel in order to save fuel costs.

In order to be in accordance with BAT, the following long list of requirements and prerequisites, of which most are not in place in the VCP today, should be secured in order to prevent and reduce the risks to the greatest extent possible prior to commencing treatment of wastes in cement kilns on a routine basis:

1. An approved environmental impact assessment EIA and all necessary national/local licences;
2. Compliance with all relevant national and local regulations;
3. BAT/BEP performance and compliance with the Basel and the Stockholm Convention;
4. Approved location, technical infrastructure and processing equipment;

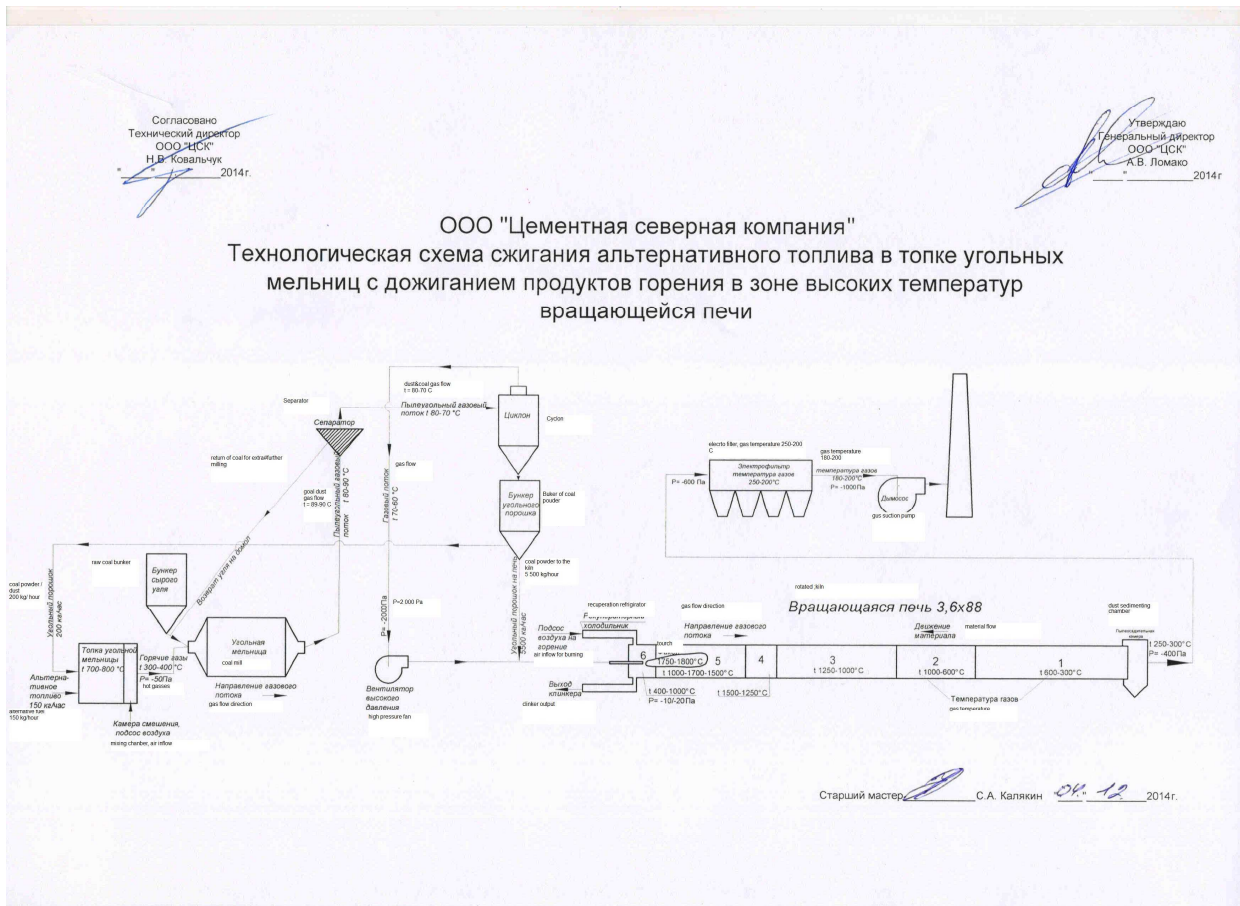
5. Reliable and adequate power and water supply;
6. Adequate air pollution control devices and continuous emission monitoring ensuring compliance with regulation and permits; needs to be verified through regular baseline monitoring;
7. Exit gas conditioning/cooling and low temperatures (<200°C) in the air pollution control device to prevent dioxin formation;
8. Clear management and organisational structure with unambiguous responsibilities, reporting lines and feedback mechanism;
9. An error reporting system for employees;
10. Qualified and skilled employees to manage wastes and health, safety and environmental issues;
11. Adequate emergency and safety equipment and procedures, and regular training;
12. Authorised and licensed collection, transport and handling of wastes;
13. Safe and sound receiving, storage, preparation and feeding of wastes;
14. Adequate laboratory facilities and equipment for waste acceptance and feeding control;
15. Demonstration of waste destruction performance through test burns;
16. Adequate record keeping of wastes and emissions;
17. Adequate product quality control routines;
18. An environmental management and continuous improvement system certified according to ISO 14001, EMAS or similar;
19. Regular independent audits, emission monitoring and reporting;
20. Regular stakeholder dialogues with local community and authorities, and for responding to comments and complaints;
21. Open disclosure of performance reports on a regular basis.

We note that the proposed equipment for continuous online monitoring is among the prerequisites for use of waste on a routine basis. But also an Environmental Management System is considered a prerequisite for proper management of complementary fuels.

The following more specific comments should not be interpreted as recommendations of the most necessary measures, in case a full systems in compliance with BAT is not considered, but rather as some comments to the current considerations of the plant as concerns the ongoing use of complementary fuel.

Feeding of waste fuel at Vorkuta cement plant

The director of the VCP indicated at a meeting with the Consultant that from his point of view the most important information that could be provided from the project would be information on where different types of waste should be fed into the kiln. For this purpose, the VCP has provided a layout of the kiln with indication of the temperature regime and flow conditions and openings for feeding of raw materials and fuel.



In the wet process, the raw material is blended with water to produce slurry a (30 to 40% moisture content) which is pumped directly into the cold end of the kiln, i.e. the kiln inlet. The slurring process helps homogenize the raw materials prior to feeding to the kiln. The wet process is the oldest and most energy intensive production process, because the water must be evaporated out of the raw material slurry mixture. Feeding alternative fuels to wet kilns makes economic sense as cost (or fuel cost) of clinker production is high compared to modern dry processes. Specific heat consumption of the wet process ranges from 5.9 to 6.7 GJ/ t of clinker produced, which is almost the double of is used in modern dry process pre-heater pre-calciner kilns.

The recommended feeding points for alternative fuels in wet kilns are either at the kiln outlet (where the primary burner is) or mid-kiln. At the kiln outlet, fine seize reduced waste materials can be fed through the main burner together with coal, or through a separate injection point in parallel to the main burner. This is the way the complementary fuel is fed into the kiln today. Vorkuta cement plant is manually

feeding whole wood sleepers and shredded/cut tyres at the kiln outlet in parallel with the coal main firing at a thermal substitution rate of 5-10%. Due to high temperature and long residence time inside the kiln, complete burnout and no influence on dioxin formation can be expected. The burning of the complementary fuel may be more efficient and stable if fine seized material is fed continuously, instead of the current bulk feeding.

At the mid-kiln, lump waste materials can be fed as alternative fuels through a mid-kiln valve, typically tyres.

Waste materials containing organic components should never be fed to the kiln inlet or together with raw material slurry, as these organic compounds will be evaporated into the exhaust gas and may act as precursors for dioxin formation in the electro static precipitator.

Ideally, the exhaust gas should also be quenched or cooled rapidly to a temperature lower than 200 °C prior to entering into the ESP to avoid PCDD/PCDF formation. However, as described elsewhere, the PCDD/PCDF emission by the current use of complementary fuel is below the limit value applied in the EU.

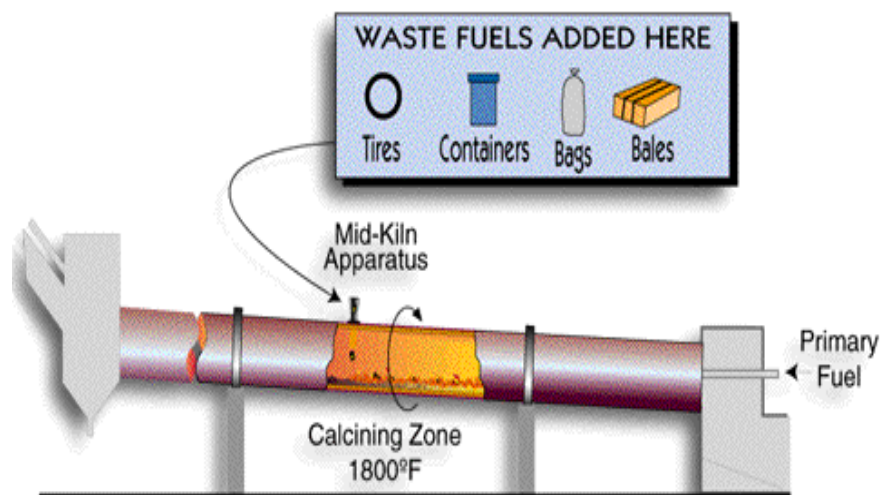


Figure 5 Feeding of complementary fuel to a wet kiln

Use of waste as complementary fuel

Currently the VCP is using tyres and sleepers as complementary fuel. The use is by the authorities not considered waste management but energy utilisation of complementary fuel. Tyres and sleepers are waste types, which are relatively easily managed, even though outdoor storage on unpaved areas without drainage may lead to soil pollution.

The VCP has considered use of other types of waste: Oil waste from oil extraction and light-weight fraction (fluff) from shredding of cars.

The oils should specifically be considered with regard to the risk of soil pollution and worker exposure because it is a liquid waste.

The co-processing of shredder waste should in particular be considered with regard to the content of PCB, mercury and chlorinated plastics - in particular PVC. The presence of chlorinated compounds and plastics makes shredder waste of particular concern due to the possible formation of PCDD/PCDF. Before any use shredder waste on routine basis, test runs with measurement of PCDD/PCDF emissions should be performed. If necessary, equipment for rapid cooling of the flue gas should be implemented. But more likely in the current situation, shredder waste should not be used as complementary fuel.

Before any new complementary fuels are introduced (in the absence of a full Environmental Management System), in coordination with the Rosprirodnadzor, at least a risk assessment and a plan for management of the fuels should be prepared, which identifies the main risk from the use of the fuel, as well as the necessary mitigation measures. The plan should also define a monitoring programme necessary to monitor if the use of the complementary fuel result in unacceptable emissions or local soil pollution. As mentioned above, today no models are available for calculating changes in emission from the use of alternative fuels. Emissions will be very dependent on the specific plant configuration.

5 Development of an action plan

The Consultant collected during the mission to Syktyvkar in 2014 information from different stakeholders regarding the future activities related to the VCP and the emissions of pollutants from the plant.

During the seminar on co-processing of waste (August 27-28 2014) and the subsequent seminar on “hot spots” (August 29 2014), it was intensively discussed between the chairman of the ACAP dioxin PSG and the Russian authorities whether the dioxin issue should be linked to the “hot spot” issue. Both the Komi MNREP and the Rosprirodnadzor for the Komi Republic expressed that in their view the VCP was listed as a “hot spot” for dust emission only and, consequently, the exclusion criteria for the VCP should only concern the dust issue. The dioxin issue was a concern raised by the ACAP dioxin PSG, and the discussions on further actions on dioxins should be separated from the “hot spot” assessment. The outcome of the seminar was that the participants agreed on separating the issues.

We suggest that the action plan is divided into two issues: Dust emission and dioxin emission. Co-processing of waste in the VCP is addressed in the previous Chapter 4.

We note that according to the proposal from COWI, the action plan includes “*recommendations to the corresponding parties on how to improve and better coordinate their respective activities*”. In our view the developed action plan includes the Consultants recommendations.

From the wrap-up meeting in Moscow November 2015, it was our impression that the action plan should be highly focused on the measures at the VCP and on actions of the VCP and the ACAP dioxin PSG.

5.1 Exclusion of the VCP as a hotspot for dust

5.1.1 Background and current situation

In the AMAP/NEFCO 2003 assessment “Updating of Environmental ‘Hot Spots’ List in the Russian Part of the Barents Region: Proposal for Environmentally Sound

Investment Projects” a joint Nordic-Russian Expert group selected the most urgent areas of concern related to pollution sources in the Russian part of the Barents Region. The selection was based on the data and information available, and the group outlined the areas of concern as an updated "hot spot" list. The method to identify "hot spots" was based on a general approach to select major polluters and/or define major environmental risk issues in each of the study regions looking at potential "hot spot" contribution to the regional environmental pollution and taking into account general pollution input, specific contaminants and trends in environmental impact. Thus specific "hot spot" inclusion criteria were not described in the 2003 report.

The JSC "Vorkuta cement factory" (VCM) was included in the 'hot spot' list with reference to inorganic dust, as the plant exceeded the maximum permitted volumes at that time.

Dust emission has as described elsewhere in this report been reduced through the implementation of an ESP filter from a level of 11,304 t/year in 2002 (AMAP 2003) and nearly 13,000 t/year of dust in 2007 and 2008 to an estimated total emission in 2014 of approximately 240 t/year. Compared with the 2002 level, the level in 2014 was about 2%, and a significant reduction has thus been obtained. Also, the dust emission level was in 2014 below the permitted maximum.

5.1.2 Exclusion criteria

No formal hot spot exclusion criteria for inorganic dust emission has been established.

The amended heavy metals protocol to the UNECE 1979 Geneva Convention on Long-range Transboundary Air Pollution (ECE/EB.AIR/115) establishes a limit values for dust emissions for cement production at 20 mg/Nm³ (Oxygen content of 10%). However, neither the amended nor the original heavy metals protocol is signed by the Russian Federation.

The VCP was included in the hot spot list because it was a significant source of dust emission in the Arctic and because the emission exceeded the permitted level.

According to information obtained from the VCP, the emission from the plant is today below the permitted volume of dust emission, and the plant does not have any requests from the authorities of further reduction of the dust emission.

In the absence of other internationally accepted exclusion criteria, it is suggested that the criteria for exclusion from the hot spot list is that the emission of inorganic dust from the plant is within the levels permitted by the supervising environmental authorities, and should this criteria be accepted, the VCP can thus be deleted from the hot spot list.

5.1.3 Stakeholders and actions

Both the Komi MNREP and the Rosprirodnadzor in Komi has expressed that they will work for the exclusion of the VCP from the hot spot list. The expected sequence of actions will follow the general procedures for exclusion of sites from the hotspot list. A number of stakeholders are involved in the process as indicated in the description below, based on information obtained in meetings with the Komi MNREP, August 2014.

The Komi MNREP intended, according to the information obtained in August 2014, to initiate the exclusion procedure September 2014. The VCP submit every 3 months information on emissions to the Komi MNREP and the Rosprirodnadzor. The intention to initiate the process is based on the information obtained from this reporting.

The Komi MNREP (represented by the local member of the BEAC Regional Working Group on Environment, RWGE) intended to request further information from the VCP. According to the obtained information, this procedure is ongoing (December 2015).

Based on this information, a letter with a recommendation of exclusion of the VCP from the hotspot list will be prepared and sent to the federal MNRE. The federal MNRE contacts the federal Rosprirodnadzor, which is responsible for industrial installations, and the federal body exchanges information with the Rosprirodnadzor in Komi which is responsible for issuing permits and supervision of the VCP. If the federal Rosprirodnadzor agrees with the recommendation, they contact the federal MNRE and the federal MNRE submit via the MNRE's member of the BEAC Working Group on Environment (WGE) a recommendation to the WGE. If necessary, the WGE would request more details from the Komi MNREP before a recommendation is submitted to the Ad-hoc Task Force on Elaboration of Procedures and Criteria on Exclusion of the Barents Environmental "Hot Spots". This group prepares the final document with a recommendation to the BEAC Ministers.

Even with a smooth process where the different bodies agree with the recommendations, the process may take several years.

For facilitating the process, it is recommended that the Komi MNREP already as an enclosure to the first recommendation letter presents as much as possible of the background material for the recommendation and clearly define the criteria on which the recommendation is based.

5.1.4 Recommendations

The problems of dust emissions from the VCP have largely been solved by installing one of the ESP units at the plant. The unit has the capacity of reducing the dust emission at the current level of cement production, but would not be sufficient if the production is increased and more of the kilns of the plant are put into operation. The installed capacity of dust control does not match the total capacity of the plant.

If the VCP is excluded from the “hot spot” list because the dust emissions are below the permitted levels, it should be ensured that the plant does not partly revert to the previous levels of dust emission, if the production volume is increased. We recommend that Rosprirodnadzor in co-ordination with the plant requires that the capacity of the ESPs are increased in due time before an increase in production to prevent the situation that dust emissions are drastically increased as a result of an increase in the production volume.

Furthermore, it is recommended that NEFCO considers the possibilities of investment in an online monitoring system, including continuous monitoring of the dust. By the online monitoring system any increase in dust emission due to malfunction of the ESP will be immediately observed, and the necessary measures can be taken. Furthermore, with an online monitoring system for dust, the ESP can be fine-tuned to improve the dust retention efficiency from the current level, which is still high as compared to international standards.

5.2 Reduction of dioxin emission from the VCP

5.2.1 Background and current situation

The ACAP PSG on Dioxins was established in 2001 and aims to "Reduce or Eliminate Emissions of Dioxins and Furans in the Russian Federation with focus on the Arctic and northern regions impacting the Arctic". Based on the results of emission inventories carried out at 61 sites in Arkhangelsk, Komi and Murmansk during Phase I (2002-2005), a priority list was produced based on which a more comprehensive review was carried out at selected emission sources during Phase II (2005-2008).

Two measurements of dioxin emission were undertaken by Institute for Hygiene, toxicology and Occupational Pathology, RF Ministry of Health, August 2004 (CIP, 2005) as part of Phase 1 of the ACAP PCDD/PCDF project. The measurements showed an emission of 0.5-0.6 ng I-TEQ/Nm³ which was close to the default emission factors of cement plants using wet technology used in the UNEP PCDD/PCDF Toolkit. The total emission from the VCP was in the ACAP PCCD/PCDF study Phase 1 report estimated at 0.735 g I-TEQ/year in 2001 based on a production of 147,000 tonnes cement. This corresponded to 18% of the estimated total PCDD/PCDF emissions from the Republic of Komi at that time.

During 2011-2013, feasibility studies were carried out at the VCP, and further assignments for sampling & analysis of emissions as well as identification of actions including emission reduction equipment were prepared by the PSG in close dialogue with the company, the authorities and NEFCO.

Measurement of PCDD/PCDF emissions from the VCP were undertaken September 2-8 2014. The results showed that the flue gas concentration, both when the plant operated with 100% coal and with a fuel composition of 5-7% tyres and railway sleepers and 93-95% coal, was within the range of 0.017 to 0.116 I-TEQ/Nm³ with an average of 0.05 ng TEQ/Nm³.

The 0.05 ng I-TEQ/Nm³ corresponds to approximately 276 ng I-TEQ per tonne of cement, and with a cement production of 120,000 tonnes in 2014, the total emission can be estimated at 0.03 g I-TEQ/year.

5.2.2 Exclusion criteria

As the dioxin pollution is not one of the criteria for inclusion of the VCP (Ko-2) in the “hot spot” list, it will not formally be relevant to define “hot spot” exclusion criteria for dioxins.

However, criteria for inclusion of the VCP in the hot spot list could be based on the limit value established in the EU for cement plants co-processing waste at 0.1 I-TEQ/Nm³. The UNECE POPs protocol (not signed by the Russian Federation), does not include limit values for cement plants, but applies the value for municipal waste incinerators. The Stockholm convention BAT document indicates for cement plants co-processing hazardous waste that a level of 0.1 I-TEQ/Nm³ can be obtained when using BAT. There is no internationally accepted definition of hazardous waste and the distinction between waste and hazardous waste differs among countries. The current waste used as supplementary fuels at the plant is not considered hazardous waste in the Russian Federation.

If the emission value of 0.1 I-TEQ/Nm³ was selected as inclusion/exclusion criteria, the VCP would meet this exclusion criteria.

5.2.3 Stakeholders and actions

The main stakeholders for further actions are the ACAP PSG on Dioxins, the VCP, and NEFCO as well as the MENR and the Rosprirodnadzor in Komi. As described in the next section, it is recommended to focus on preventing any future increase in the emission.

5.2.4 Recommendations

As the current emission is below the EU limit value of 0.1 I-TEQ/Nm³, and no limit values and requirements exist in Russia, it is not recommended to establish further abatement measures for dioxins and furans, even though a fast cooling of the flue gas in a cooling tower may result in a reduction of the PCDD/PCDF emission from the plant.

It is recommended to focus on preventing any future increase of PCDD/PCDF emission from the plant.

If the plant considers to increase the use of waste as complementary fuel and use other types of complementary fuel than used today, as a minimum a risk assessment as described in section 4.2 should be performed and the necessary measures should be taken following the overall guidelines described in Annex 2.

Ideally, all procedures mentioned in Annex 2 should be followed, including the implementation of an online monitoring system and an Environmental Management System.

Annex 2 includes a list of waste which should never be used as complementary fuel. Furthermore, it is proposed not to use the cement plant for destruction of hazardous waste, e.g. pesticides or PCB-contaminated oil. Until the necessary procedures have been implemented, it is furthermore recommended not to use waste with high chlorine content and an unknown content of POPs and mercury (e.g. car fluffs or municipal solid waste), other waste with a high content of chlorine (e.g. PVC) or liquid waste with the potential for soil and groundwater pollution.

6 Abbreviations and acronyms

ACAP	Arctic Contaminants Action Program
BAT	Best available techniques
ESP	Electrostatic precipitator
EU	European Union
GOST	Gosudarstvennyy standart (Russian state standard)
MNREP	Ministry of Natural Resources and Environmental Protection (of the Komi Republic)
PCB	Polychlorinated biphenyls
PCDD	Polychlorinated dibenzo- <i>p</i> -dioxins
PCDF	Polychlorinated dibenzofurans
PSG	Project steering committee (of the ACAP dioxin project)
TEQ	Toxicity equivalent (of dioxin toxicity)
ToR	Terms of Reference
VCP	Vorkuta Cement Plant

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Appendix 1 Supervision of sampling and comments to results

App. 1.1 Review of design of measuring programme and sampling and analytical procedures

Based on the description of the measuring programme in the Terms of Reference for Polar Fund /Typhoon, the Consultant has suggested various changes to the design of the programme. The proposed changes were discussed during a meeting with the ACAP dioxin PSG, Polar Fund and the VCP director and were further specified in a memo of September 1 “*Comments to the design of the PCDD/PCDF measuring programme*”.

Based on the comments the measuring programme was revised as suggested by the Consultant.

According to material received from Typhoon, the methodology to be applied for sampling and analysis is based on the Russian standard ПНД Ф 13.1.65-08. The Russian standard (in Russian only) indicates that the sampling procedures are based on EN 1948-1 “*Stationary source emissions. Determination of the mass concentration of PCDDs/PCDFs and dioxin-like PCBs. Sampling of PCDDs/PCDFs*”, which is the method used in the EU for measuring dioxin emission from industrial sources. A review of a translation of the Russian standard did only identify one substantial difference between the sampling procedures described in the Russian standard and EN 1948-1.

The Russian standard ПНД Ф 13.1.65-08 is apparently based on the same analytical procedures as described in the European standard EN 1948-2 (clean-up procedures) and 1948-3 (analysis and calculation of TEQ). However, it is considered that applying the same procedures is not a guarantee of the quality of the clean-up and analysis, as Typhoon does not hold an accreditation of the analysis of dioxins (such a system does not exist in Russia).

The Consultant has therefore requested relevant documentation in the form of the results of Typhoon’s performance in international inter-calibration studies, which is the only way to assess the quality of the laboratory’s analyses. The results have so far not been provided.

App. 1.2 Supervision of sampling in the VCP

Collection of samples for analysis of emission of PCDD/PCDF and other pollutants from the VCP took place during a sampling campaign in Vorkuta September 2-8, 2014. The Consultant participated in the start of the campaign (September 2-4), where sites for sampling and sampling procedures were clarified.



The probe is introduced into the duct by the measuring team



The sampling platform – the flue gas flows in downward direction

It should be noted that the ToR for the sampling and analysis do not include any requirement that the Polar Fund/Typhoon should exchange any information with COWI, and the ToR do not indicate that the laboratory should follow any changes in sampling and analytical procedures suggested by COWI based on European best practice.

Sampling procedure

The overall impression was that the Typhoon sample team was very experienced in the sampling methodology and procedures and has detailed knowledge to the Russian standard for PCDD/PCDF sampling and analysis. The equipment is assessed to be adequate for the sampling. The sampling team had just before this campaign been measuring PCDD/PCDF emissions from one of the largest cement plants in Russia. According to the team PCDD/PCDF emissions are usually requested by plants as part of their planning for using alternative fuels.

As mentioned in the memo of September 1 "*Comments to the design of the PCDD/PCDF measuring programme*" the Consultant has informed Typhoon that the European standard EN 1948-1 prescribes that the equipment is rinsed in acetone first and afterwards with toluene whereas the Russian standard indicated that the trap is rinsed in acetone only. The acetone removes the water whereas the toluene removes the dioxins. Hence, using acetone only would not adequately rinse the trap. The sampling team from Typhoon informed that they were not in a position to make changes in the procedures on the request of the Consultant, as it was their responsibility that the sampling was done in accordance with the standard. Changes in cleaning procedures could be a question for the experts who develop the standard. Not using toluene might slightly underestimate the PCDD/PCDF concentration, which will be noted in the Consultant's interpretation of the results.

Sampling site and flow

The sampling platform was established on the duct between the electrostatic precipitator (ESP) and the stack where samples of air pollutants are regularly collected at the VCP. The duct was at the sampling site square-sized with 1.8 m at each side. Upstream the sampling site, the duct was straight for approximately 6 meter. Both the Typhoon team and the Consultant noted that the sample site was not optimal for having laminar flow conditions (would require a straight duct for about 8 meter), but it was found to be acceptable. In any case, it was not possible to point at any better sampling site. The temperature of the flue gas was below 200 °C, which is a prerequisite of the standard.

The Russian standard and EN 1948-1 prescribe that the sampling should be carried out at a representative point in the channel of the duct and the location of this point is determined by preparing a profile of the flow. The measurements are undertaken iso-kinetically i.e. the flow through the sample equipment is proportional to the flow in the measuring point in the duct. Based on the measurements done in accordance with the standards it is possible to calculate the emissions in terms of concentrations in ng TEQ/Nm³ but not the emission in terms of quantities in ng TEQ/h. Determining the emission in ng TEQ/h is necessary if emissions in ng TEQ/tonne cement produced (as requested in the ToR) should be calculated.

For the latter the flow in the duct should be known. In the EU, the flow is determined accordance with the EN ISO 16911 "*Stationary source emissions. Manual and automatic determination of velocity and volume flow rate in ducts*". The Russian standard for PCDD/PCDF measurements does not make reference to measurements of total flows and the Russian team did not expect that the flow in the duct should be determined (these measurements are usually not required). The determination of flows in the duct was not specifically indicated in the ToR for Ty-

phoon and, apparently, none of the organisations had noticed the consequences of the request of expressing the concentration on terms of tonne cement produced. For this reason, Typhoon did not bring equipment for this determination. Furthermore, the team did not have a certificate for undertaking these measurements. After consultation with the expert from Force Technology, it was decided that the team should perform two-directional profiles of the flow in the duct with the available flow measuring equipment and these profiles could be used for an approximate determination of the flow in the duct by a two-dimensional integration. For the current use of the results, this is considered to be acceptable, as the determining parameter will be the concentration in ng TEQ/Nm³. The relationship between the emissions in terms of concentration and in the terms of tonne produced cement will later be assessed by the consultant by comparing with the experience from other cement plants using the wet process (as indicated in the UNEP toolkit for PCDD/PCDF inventories).

Time of the sampling

In the memo of September 1 "*Comments to the design of the PCDD/PCDF measuring programme*" the Consultant suggests on the basis of Danish guidelines that the sampling time should be 6 hours in order to reflect variation in emissions. Typhoon are used to sample for one hour only and expected that the sample filter would be clogged with dust after one to two hours. It was confirmed by the expert from Force Technology that in cement plants equipped with ESPs only, it could be likely that dust could be limiting factor for the sampling time. It was agreed that Typhoon should try to sample for as much time as possible within the limits of equipment.

After the first sampling it was concluded that dust would not be a limiting factor but condensed water limited the sampling beyond a sampling time of 1½ hour. It was agreed that the sampling time should be as long as possible under the sampling conditions but not more than 6 hours.

In order to reflect the possible variation in emissions it was agreed that the samples for each of the two situations (with and without alternative fuels) should be measured over two days even though it would have been possible to run all four samples in one day.

Measurements of mercury

During the sampling campaign, the ACAP PSG raised a question about measurements of mercury. In the ToR for the Polar Fund it is indicated that mercury is measured in the dust only. The ACAP PSG asked if measurements of mercury in air emissions could be included in the programme. The consultant answered that the sampling team did not bring equipment for measuring mercury emission (as it was not included in the ToR), and that it would not be possible to include these measurements in this sampling campaign.

Use of alternative fuels

For some technical reasons the production was stopped September 1. When the team arrived September 2, the plant used 100% coal as fuel. It was for this reason decided to postpone the sampling until September 3 and then first take 4 samples without alternative fuels and subsequently take 4 samples where tires and sleepers

accounted for 5-7% of the fuel input (first samples after 24 hours with alternative fuel).

The alternative fuel is introduced as full sleepers and half tyres. The fuel is introduced into a burning chamber at the lower end of the kiln where the burning dust coal is forced into the kiln. The fuel is not introduced into the kiln itself. The tyres are cut manually into two parts with an angle grinder. The cutting results in formation of heavy rubber fumes and the working environment conditions are not optimal. It is obvious that the use of alternative fuels, beyond the current test runs, would require improved pre-treatment and loading of the fuel.

Ap.1.3 Comments to obtained results

Comments to the report prepared by Polar Foundation and analytical results of Umeå University have been provided during the period.

The following responses have been prepared during the entire period:

Written responses in notes:

- › 12 Nov 2014
- › 30 Jan 2015
- › 27 Apr 2015
- › 15 Jul 2015
- › 10 Nov 2015

Comments to the report Nov 2015 (written directly in report) included a re-editing and re-formatting of the report in order to illustrate how the report could be formatted in order to meet international standards for technical reports.

Written responses in emails with substantial comments:

- › 5 Nov 2014
- › 12 Nov 2014
- › 14 Jan 2015
- › 20 Jan 2015
- › 26 Jan 2015
- › 7 Apr 2015
- › 21 May 2015
- › 3 Jun 2015
- › 1 Sep 2015
- › 4 Nov 2015
- › 6 Nov 2015
- › 8 Nov 2015
- › 9 Nov 2015
- › 10 Nov 2015
- › 2 Dec 2015
- › 28 Jan 2016

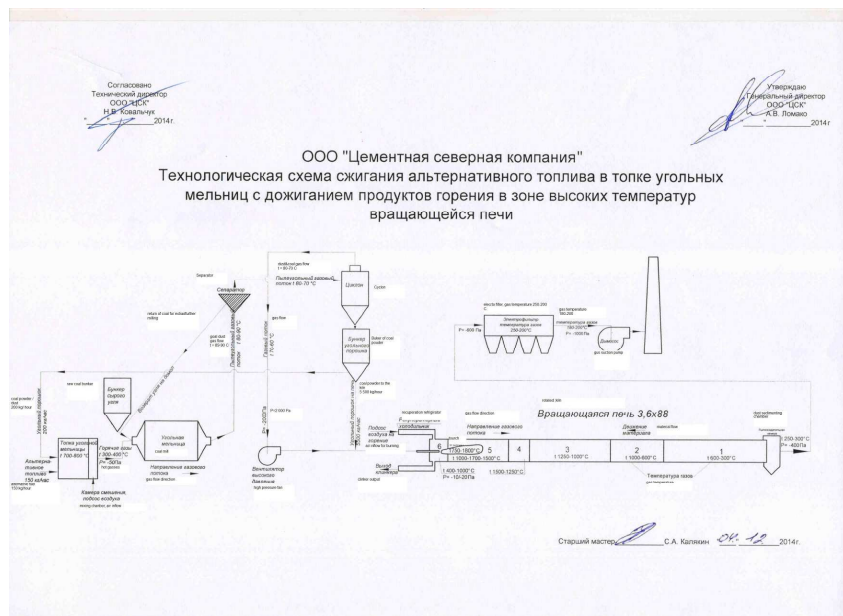
Teleconferences with the ACAP Dioxins Steering Group

- › 10 Nov 2014
- › 13 Feb 2015
- › 13 Jul 2015
- › 4 Sep 2015

Furthermore, a large number of emails with small comments, clarifications etc. have during the period been exchanged between COWI and NEFCO/ACAP SG members, Umeå University and Polar Foundation.

Appendix 2 Recommendations regarding the use of alternative fuels based on waste

Co-processing of wastes as alternative fuels at Vorkuta cement plant, Komi Republic, Russian Federation



Dr Kåre Helge Karstensen

Oslo 18 January 2015



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1 Introduction

Vorkuta cement plant in Komi Republic has 3 wet kilns; Kiln #1 with a capacity of 11.3 t/h, Kiln #2 & #3 each with a capacity of 17 t/h. The plant has no exit air quenching system or pollution control system in place and the current emission of dust is measured to 6 000 – 24 000 mg/Nm³. Two measurements of dioxin emissions conducted 25 August 2004 showed an emission of 0.5-0.6 ng TEQ/Nm³. The EU standard is

The objective of this report is to describe best practice with regards to co-processing of wastes as alternative fuels.

1.1 General guiding principles for using waste as fuel

The use of wastes must not detract from smooth and continuous cement kiln operation, product quality, or the site's normal environmental performance implying that wastes used in cement kilns must be homogenous and have a stable chemical composition and heat content, and a pre-specified size distribution. Pre-processing and preparation with the objective of providing a more homogeneous feed and more stable combustion conditions may therefore be necessary.

The following requirements and prerequisites should be in place to prevent and reduce the risks to the greatest extent possible prior to commencing on with treatment of wastes in cement kilns on a routine basis:

1. An approved environmental impact assessment EIA and all necessary national/local licences;

2. Compliance with all relevant national and local regulations;
3. BAT/BEP performance and compliance with the Basel and the Stockholm Convention;
4. Approved location, technical infrastructure and processing equipment;
5. Reliable and adequate power and water supply;
6. Adequate air pollution control devices and continuous emission monitoring ensuring compliance with regulation and permits; needs to be verified through regular baseline monitoring;
7. Exit gas conditioning/cooling and low temperatures (<200°C) in the air pollution control device to prevent dioxin formation;
8. Clear management and organisational structure with unambiguous responsibilities, reporting lines and feedback mechanism;
9. An error reporting system for employees;
10. Qualified and skilled employees to manage wastes and health, safety and environmental issues;
11. Adequate emergency and safety equipment and procedures, and regular training;
12. Authorised and licensed collection, transport and handling of wastes;
13. Safe and sound receiving, storage, preparation and feeding of wastes;
14. Adequate laboratory facilities and equipment for waste acceptance and feeding control;
15. Demonstration of waste destruction performance through test burns;
16. Adequate record keeping of wastes and emissions;
17. Adequate product quality control routines;

18. An environmental management and continuous improvement system certified according to ISO 14001, EMAS or similar;
19. Regular independent audits, emission monitoring and reporting;
20. Regular stakeholder dialogues with local community and authorities, and for responding to comments and complaints;
21. Open disclosure of performance reports on a regular basis.

1.2 Formation of dioxins

Formation of PCDD/PCDFs in cement kilns can result from a combination of mechanisms, depending on kiln and process configuration, process and combustion conditions, fuel and waste feed characteristics, and type and operation of the air pollution control device.

New synthesis of PCDD/PCDFs needs some essential building blocks, carbon or organic compounds, chlorine and oxygen:

1. Carbonaceous/organic compounds will be the starting point for the new synthesis of PCDD/PCDFs; a wide variety of compounds may suit the purpose, from plain carbon, to aliphatic and aromatic hydrocarbons;
2. Chlorine;
3. Oxidizing conditions, i.e. surplus oxygen.
4. A temperature of 200-400°C for heterogeneous solid-phase reactions and 500-800°C for homogeneous gas-phase reactions;
5. Sufficient residence time;
6. Catalysts and/or particulate surfaces

Organic emissions from cement kilns can have three potential sources: unburnt fuel and wastes, volatilisation of embedded organic compounds in the raw meal, and compounds newly formed via reactions in the kiln/air pollution control device/preheater, often-called products of incomplete combustion, PICs.

1.3 BAT/BEP for controlling emissions of PCDD/PCDFs

A smooth and stable kiln process, operating close to the process parameter set points is beneficial for all kiln emissions as well as the energy use. PCDD/PCDF control in cement production becomes a simultaneous effort to reduce the precursor and/or organic concentrations, preferably by finding a combination of optimum production rate and optimum gas temperatures and oxygen level at the raw material feed end of the kiln, and reducing the air pollution control device (APCD) temperature.

The most important measure to avoid PCDD/PCDF formation in wet kilns seems to be quick cooling of the kiln exhaust gases to lower than 200 °C. Modern preheater and precalciner kilns have this feature already inherent in the process design and have APCD temperatures less than 150 °C. Operating practices such as minimising the build-up particulate matter on surfaces can assist in maintaining low PCDD/PCDF emissions. Feeding of alternative raw materials as part of raw material mix should be avoided if it includes elevated concentrations of organics and no alternative fuels should be fed during start-up and shut down.

2 Cement manufacturing

There are four main process routes in the manufacturing of cement – the dry, semi-dry, semi-wet and wet process. The main features of these processes are described in more detail in the following chapters. Common to all these processes are the following sub-processes:

- Quarrying;
- Raw materials preparation;
- Fuels preparation;
- Clinker burning;
- Mineral additions preparation;
- Cement grinding;
- Cement dispatch.

2.1 The four main process routes

Historically, the development of the clinker manufacturing process was characterised by the change from “wet” to “dry” systems with the intermediate steps of the “semi-wet” and “semi-dry” process routes. The first rotary kilns – introduced around 1895 – were long wet kilns.

“Wet” kilns allowed for an easier handling and homogenisation of the raw materials, especially in cases when the raw materials are wet and sticky or exhibit large fluctuations in the chemical composition of the individual raw mix components. With more advanced modern technology however, it is possible to prepare a homogeneous raw meal using the “dry” process, i.e. without addition of water to prepare raw slurry. The main advantage of a modern dry process over a traditional wet system is the far lower fuel consumption and thus, lower fuel cost. Today, the selection of the wet process is only feasible under very specific raw material and process conditions.

The four different basic processes can be briefly characterised as follows:

- Dry process: Dry raw meal is fed to a cyclone preheater or precalciner kiln or, in some cases, to a long dry kiln with internal chain preheater.
- Semi-dry process: Dry raw meal is pelletised with water and fed to a travelling grate preheater prior to the rotary kiln or in some cases, to a long kiln equipped with internal cross preheaters.
- Semi-wet process: Raw slurry is first dewatered in filter presses. The resulting filter cake is either extruded into pellets and fed to a travelling grate preheater or fed directly to a filter cake drier for (dry) raw meal production prior to a preheater/precalciner kiln.
- Wet process: The raw slurry is fed either directly to a long rotary kiln equipped with an internal drying/preheating system (conventional wet process) or to slurry drier prior to a preheater/precalciner kiln (modern wet process).

2.2 Process technological characteristics of clinker production

All processes have in common that the kiln feed is first dried, then calcined by dissociation of carbon dioxide (CO_2) from the CaCO_3 in the feed material, and finally sintered to clinker at temperatures between 1400 and 1450 °C. During this process the feed loses approximately one third of its original dry mass. The hot clinker is cooled by air to 100-200 °C in a clinker cooler. The heated air is used as secondary combustion air in the kiln.

2.3 The wet process

Conventional wet process kilns are the oldest type of rotary kilns to produce clinker. Wet kiln feed (raw slurry) typically contains 28 to 43 % of water which is added to the raw mill (slurry drums, wash mills and/or tube mills). Batch blending and homogenisation is achieved in special slurry silos or slurry basins where compressed air is introduced and the slurry is continuously stirred.

The slurry is pumped into the rotary kiln where the water has to be evaporated in the drying zone at the kiln inlet. The drying zone is designed with chains and crosses to facilitate the heat exchange between the kiln feed and the combustion gases. After having passed the drying zone, the raw material moves down the kiln to be calcined and burnt to clinker in the sintering zone.

Conventional wet kiln technology has high heat consumption and produces large volumes of combustion gases and water vapour. Wet rotary kilns may reach a total length of up to 240 m compared to short dry kilns of 55 to 65 meter length (without the preheater section).

In modern wet kiln systems, the raw slurry is fed to slurry drier where the water is evaporated prior to the dried raw meal entering a cyclone preheater/precalciner kiln. Modern wet kiln systems have a far lower specific heat consumption compared to conventional wet kilns.

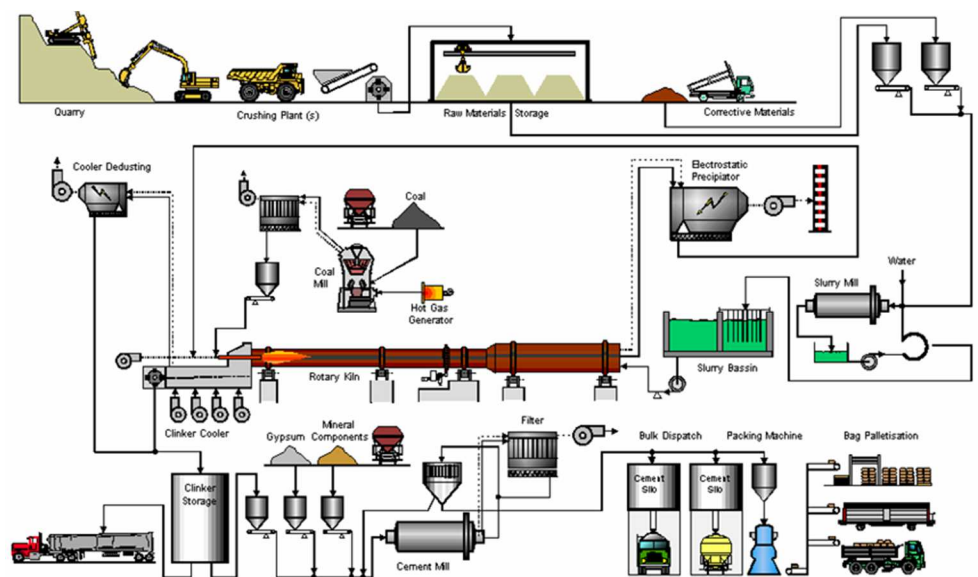


Figure 6 Wet process

2.4 Fuels

Main fossil fuels (“primary” fuels) in the cement industry are coal, petcoke, heavy oil, and – to a lesser extent – natural gas. Non-fossil “alternative” fuels derived from industrial sources such as tyres, waste oil, plastics, solvents and many more are commonly used as substitute fuels today. The chemical components of the ash of solid fuels combine with the raw materials and will be fully incorporated in the clinker produced. Thus, the chemical composition of the ash has to be considered in the raw mix design.

In the same way as the major elements, metals which may be introduced with liquid or solid fuels will also be incorporated into the clinker structure to a large extent. Exceptions are metals which are partly or completely volatilised in the kiln system such as mercury, thallium or cadmium. These elements will be captured in the kiln (filter) dust or may to some extent escape with the stack emissions (mercury) if not managed appropriately.

2.5 Fuels preparation

The physical nature of the fuels used in a cement plant – solid, liquid or gaseous – determines the design of the storage, preparation and firing systems – both for conventional fossil fuels and for alternative fuels from industrial sources. The main fuel input has to be delivered in a form that allows uniform and reliable metering as well as easy and complete combustion. This is usually the case with all pulverised, liquid and gaseous fuels. A limited input (up to 35 %) may also be delivered by the addition of coarse materials at specific feed points.

Coal and petcoke are ground to fineness similar to raw meal in coal mills (tube mills, vertical roller mills or impact mills). For safety reasons, the whole coal preparation system is designed for protection from fire or explosion. The pulverised fuel may be fed directly to the burner (without intermediate storage and metering system) or – which is common practice today – may be stored in fine coal silos with adequate metering and feeding systems.

Fuel oil is stored in large tanks on site. Handling is facilitated by heating up the oil to a temperature of about 80 °C. Metering and combustion are facilitated by addi-

tional heating of the oil up to a temperature of 120-140 °C, resulting in a reduction of the viscosity.

Natural gas is delivered by national or international distribution systems without on-site storage. Prior to combustion in the kiln, the pressure of the gas has to be reduced to the plant's network pressure in gas transfer stations where also the fuel metering takes place.

Alternative fuels originating from industrial sources may require specific treatment. Gaseous, liquid and pulverised or fine crushed solid fuels can be fed to the kiln system similarly to the fossil fuels mentioned above. Coarsely shredded or even bulky materials can be fed to the preheater/precalciner section or, rarely, to the mid kiln section only. For process reasons, the contribution of bulky fuels to the total heat consumption should be limited to about 15 to 30 % depending on the kiln system.

Alternative fuels are frequently prepared and blended outside the cement plant by specialised companies in facilities specifically designed for this purpose. The cement plant has to provide the storage and feeding systems only on site. Alternative fuel plants are often designed as "multi-purpose plants" in order to handle a variety of different wastes.

2.6 Characteristics of the cement production process - a summary

In the burning of cement clinker it is necessary to maintain material temperatures of up to 1450 °C in order to ensure the sintering reactions required. This is achieved by applying peak combustion temperatures of about 2000 °C with the main burner flame. The combustion gases from the main burner remain at a temperature above 1200 °C for at least 5-10 seconds.

An excess of oxygen – typically 2-3 % – is also required in the combustion gases of the rotary kiln as the clinker needs to be burned under oxidising conditions. These conditions are essential for the formation of the clinker phases and the quality of the finished cement.

The retention time of the kiln charge in the rotary kiln is 20-30 and up to 60 minutes depending on the length of the kiln. The figure below illustrates the temperature

profiles for the combustion gases and the material for a preheater/precalciner rotary kiln system. While the temperature profiles may be different for the various kiln types, the peak gas and material temperatures described above have to be maintained in any case.

The burning conditions in kilns with precalciner firing depend on the precalciner design. Gas temperatures from a precalciner burner are typically around 1100 °C, and the gas retention time in the precalciner is approximately 3 seconds.

Under the conditions prevailing in a cement kiln – i.e. flame temperatures of up to 2000 °C, material temperatures of up to 1450 °C and gas retention times of up to 10 seconds at temperatures between 1200 and 2000 °C – all kinds of organic compounds fed to the main burner with the fuels are reliably destroyed.

The combustion process in the main flame of the rotary kiln is therefore complete. No (hydrocarbon type) products of incomplete combustion can be identified in the combustion gases of the main burner at steady-state conditions.

The cement manufacturing process is an industrial process where large material volumes are turned into commercial products, i.e. clinker and cement. Cement kilns operate continuously all through the year – 24 hours a day – with only minor interruptions for maintenance and repair.

A smooth kiln operation is necessary in a cement plant in order to meet production targets and to meet the quality requirements of the products. Consequently, to achieve these goals, all relevant process parameters are permanently monitored and recorded including the analytical control of all raw materials, fuels, intermediate and finished products as well as environmental monitoring.

With these prerequisites – i.e. large material flow, continuous operation and comprehensive process and product control, the cement manufacturing process seems to be well suited for co-processing by-products and residues from industrial sources, both as raw materials and fuels substitutes and as mineral additions.

The selection of appropriate feed points is essential for environmentally sound co-processing of alternative materials, i.e.:

- Raw materials: mineral waste free of organic compounds can be added to the raw meal or raw slurry preparation system. Mineral wastes containing significantly quantities of organic components are introduced via the solid

fuels handling system, i.e. directly to the main burner, to the secondary firing or, rarely, to the calcining zone of a long wet kiln ("mid-kiln").

- Fuels: alternative fuels are fed to the main burner, to the secondary firing in the preheater/precalciner section, or to the mid-kiln zone of a long wet kiln.
- Mineral additions: mineral additions such as granulated blast furnace slag, fly ash from thermal power plants or industrial gypsum are fed to the cement mill. In Europe, the type of mineral additions permitted is regulated by the cement standards.
- In addition to regulatory requirements, the cement producers have set up self- limitations such as
 - To prevent potential abuse of the cement kiln system in waste recovery operations
 - To assure the required product quality
 - To protect the manufacturing process from operational problems
 - To avoid negative impacts to the environment, and
 - To ensure workers' health and safety.

The cement manufacturing process is a large materials throughput process with continuous operation and comprehensive operational control. Therefore, it has a large potential for co-processing a variety of materials from industrial sources.

3 Utilisation of alternative fuels and raw materials in cement production

Wastes and hazardous wastes in the environment represent a challenge for many countries, but cement kiln co-processing can constitute a sound and affordable recovery option. Cement kilns can destroy organic hazardous wastes in a safe and sound manner when properly operated and will be mutually beneficial to both industry, which generates such wastes, and to the society who want to dispose properly of such wastes in a safe and environmentally acceptable manner. The added benefit of non renewable fossil energy conservation is important, since large quantities of valuable natural fuel can be saved in the manufacture of cement when such techniques are employed.

3.1 Theory of combustion

Combustion is a combination of pyrolysis and oxidation. Pyrolysis is a chemical change resulting from heat alone. Oxidation is the gross reaction of an organic species with oxygen and requires relatively low activation energies. Pyrolysis involves the breaking of stable chemical bonds, often resulting in molecular rearrangement, and higher molecular weight products. Pyrolysis occurs in a time scale of seconds, while oxidation occurs in milliseconds.

For efficient combustion, oxidation should be the dominant process, with pyrolysis occurring either incidentally to the oxidation or to put a material into a better physical form for oxidation.

To combust wastes effectively, pyrolysis must be efficient and complete before oxidation of the molecular chemical by-products can occur. This is why cement kilns are ideal; with material temperature at approximately 1450 °C and kiln gas temperatures up to 2000 °C, long residence time up to 8 seconds, or more, insures complete pyrolysis or breakdown of organic wastes. Complete oxidation can then easily follow.

Combustion temperature and residence time for mixed hazardous wastes cannot be readily calculated and are often determined empirically. Some common solvents such as alcohols and toluene can easily be combusted at about 1000 °C and one second residence time, while other more complex organic halogens require more stringent conditions such as the US EPA Toxic Substances Control Act (TSCA) PCB incineration criteria of 1200 °C and 2 sec residence time.

In order to co-process organic wastes in cement kilns properly, it is important to know and control the parameters given in Table 1.

Table 1 Information needed for combustion of waste materials

<u>Critical waste incineration parameters</u>	<u>Physical and chemical properties</u>
Ultimate analysis	C, H, O, N, H ₂ O, S and ash composition
Metals	Na, K, Cu, V, Ni, Fe, Pb, Hg, Tl etc.
Halogens	Chlorides, bromides, fluorides
Heating value	Joule or cal/gram
Solids	Size, form and quantity
Liquids	Viscosity, specific gravity and impurities
Gases	Density and impurities
Organic portion	Percentage
Special characteristics	Corrosiveness, reactivity, flammability
Toxicity	Carcinogenicity, aquatic toxicity, etc

3.2 AFR use in the cement industry

Since the early 1970s, and particularly since the mid-1980s, alternative – i.e. non-fossil – raw materials and fuels derived mainly from industrial sources have been beneficially utilised in the cement industry for economic reasons. Since that time, it has been demonstrated both in daily operations and in numerous tests that the overall environmental performance of a cement plant is not impaired by this practice in an appropriately managed plant operation.

Cement kilns make full use of both the calorific and the mineral content of alternative materials. Fossil fuels such as coal or crude oil are substituted by combustible materials which otherwise would often be landfilled or incinerated in specialised facilities.

The mineral part of alternative fuels (ashes) as well as non-combustible industrial residues or by-products can substitute for part of the natural raw materials (limestone's, clay, etc.). All components are effectively incorporated into the product, and – with few exceptions – no residues are left for disposal. The use of mineral additions from industrial sources substituting clinker saves both raw material resources and energy resources as the energy intensive clinker production can be reduced.

With the substitution of fossil fuels by (renewable) alternative fuels, the overall output of thermal CO₂ is reduced. A thermal substitution rate of 40 % in a cement plant with an annual production of 1 million tons of clinker reduces the net CO₂ generation by about 100,000 tons. Substitution of clinker by mineral additions may be more important as both thermal CO₂ from fossil fuels and CO₂ from the decarbonation of raw materials is reduced.

Since only moderate investments are needed, cement plants can recover adequate wastes at lower costs than would be required for landfilling or treatment in specialised incinerators. In addition, public investment required for the installation of new specialised incinerators would also be reduced.

Substitute materials derived from waste streams usually reduce the production cost in cement manufacturing, thus strengthening the position of the industry particularly with regard to imports from countries with less stringent environmental legislation.

It will also facilitate the industry's development of technologies to further clean up atmospheric emissions.

4 General considerations for using waste as fuel

This chapter summarise general measures and considerations, which needs to be in place when starting with pre-processing and co-processing in cement plants.

4.1 Compliance with regulations

Relevant and appropriate legislative and regulatory framework has to be in place and enforced to guarantee a high level of environmental protection. The pre-processing facility and cement plant operator must:

- a) Identify all relevant laws, regulations, permits, standards, and company policies relating to safety, health, environment, and quality control, and its compliance must be continually reviewed;
- b) Share this information with the employees and make sure that they are aware of their responsibilities under them.

4.2 Location, health and safety aspects

Consider site location of the pre-processing and the co-processing plant and its suitability carefully as this may avoid risks associated with proximity to populations of concerns, impact of releases, logistics, transport, infrastructure, as well as having in place technical solutions for vapours, odours, infiltration into environmental media, etc. The pre-processing facility and cement plant operator must:

- a) Develop robust emergency procedures as well as procedures for operation and maintenance that cover safety of neighbours, workers and installations;
- b) Systematically review operation and maintenance procedures.

4.3 Training

The pre-processing facility and cement plant operator must develop and implement appropriate and documented training programs for employees on operation, safety, health, and environment and quality issues relevant to their jobs. Train new employees during an induction process and personnel reporting to work on a site for the first time should be trained through a site induction program. Keep training records on file. The training program should include the following:

- a) General and job specific safety rules;
- b) Safe operation of all equipment;
- c) Compliance with existing permits for working with waste;
- d) Details of the site emergency plan and procedures;
- e) Procedures for handling wastes and alternative fuels and raw materials as well as detection of warning indicators such as barrel expansion, smoke from stockpiles, spillages or leaks;
- f) Use and maintenance of personal protective equipment (PPE);
- g) Waste labelling (composition, storage requirements and risks) and requirements for segregation of incompatible wastes (such as minimum distances, firewalls and containment cells).
- h) Such training programs should also be given to contractors and, in some instances, suppliers.

4.4 Involvement and communication

Adequate documentation and information are mandatory, providing an informed basis for openness and transparency about health and safety measures and standards, and ensuring that employees and authorities have such information well before starting any use of waste. All relevant authorities have to be involved during

the permitting process and the pre-processing facility and cement plant operator must:

- a) Establish credibility through open, consistent, and continuous communication with the authorities and other involved stakeholders. All necessary information must be provided to allow stakeholders to understand the purpose of co-processing AFRs in a cement kiln, the context, the function of the parties involved and decision-making procedures;
- b) Provide necessary information to ensure that authorities are able to evaluate and understand the entire process;
- c) Establish a stakeholder engagement plan for working with the local community and authorities, including procedures for responding to community interests, comments, or complaints; give prompt feedback.

4.5 Reporting performance

Building trust with stakeholders requires both transparency and accountability in the cement plant operator and its site operations. The production of regular reports on performance in all areas of interest helps to provide key stakeholders with the information they need to make a fair and balanced judgment of the company's or site's activities and performance.

4.6 Environmentally sound management

Environmentally sound management (ESM) is a policy concept that more broadly applies to wastes within the Basel and Stockholm Convention. In its article 2, paragraph 8, the Basel Convention (1989; 2006) defines ESM of wastes or other wastes as *“taking all practicable steps to ensure that wastes or other wastes are managed in a manner which will protect human health and the environment against adverse effects which may result from such wastes.”*

To comply with the ESM criteria, a number of legal, institutional and technical conditions must be met, in particular that:

- a) A regulatory and enforcement infrastructure ensures compliance with applicable regulations;
- b) The facility should be authorized and have an adequate standard of technology and pollution control to deal with wastes;
- c) The facility should have an applicable environmental management system (EMS) in place;
- d) The facility should take sufficient measures to safeguard occupational and environmental health and safety;
- e) The facility should have an adequate monitoring, recording and reporting programme;
- f) People involved in the management of wastes are capable and adequately trained in their capacity.
- g) That the facility should have an adequate emergency plan; and
- h) The effects of the activities needs to be monitored and appropriate action should be taken in cases where monitoring gives indications that the management of wastes has resulted in unacceptable releases.

4.7 Environmental management system

The pre-processing facility and cement plant operator should have an environmental management system (EMS) in place, ensuring continuous improvement of its performance. The two most frequently used guidelines for EMS design are the international standard, ISO 14001, and the European standard, EMAS.

ISO 14001 provides guidelines that can be implemented by almost any type of organization in any country and was designed primarily to improve management. EMAS, on the other hand, is designed to bring about changes in environmental performance. Preparing for and complying with ISO 14001 involves several steps:

- a) Conducting an initial environmental review;
- b) Identifying environmental aspects and impacts;

- c) Setting an environmental policy;
- d) Understanding and complying with local environmental legislation and regulations and other standards to which the organization subscribes;
- e) Setting environmental objectives and targets;
- f) Setting and implementing an environmental management program;
- g) Setting and implementing environmental procedures;
- h) Establishing environmental training and awareness;
- i) Establishing an environmental communication system;
- j) Establishing a system for document and operational control;
- k) Installing an emergency preparedness and response plan;
- l) Monitoring and measuring;
- m) Understanding non-conformance and implementing correction and prevention;
- n) Having an audit, and
- o) Management review and control.

5 Initial waste and impact evaluation by the cement plant

The aim of the initial acceptance procedures is to set the outer boundaries and limits for wastes, which can be accepted by a particular kiln, and the conditions and requirements for their preparation and delivery specification. Any waste fed to a cement kiln should:

- a) Be homogenous;

- b) Have stable heat and moisture content;
- c) Have stable chemical and physical composition;
- d) Have a pre-specified size distribution.

In real-life, a cement plant operator usually receives wastes from various producers with various waste characteristics and to fulfil the requirements mentioned above wastes must be pre-processed prior to delivering to the cement plant. The cement plant operator must however specify their requirements for waste acceptance with the waste owner and the pre-processing facility prior to any deliverables.

5.1 Waste evaluation

Accept only wastes from trustworthy parties throughout the supply chain, with traceability ensured prior to reception by the facility and with unsuitable wastes refused. The pre-processing facility and cement plant operator must develop an evaluation and acceptance procedure that includes the following features:

- a) To evaluate possible impacts before delivering it to the cement plant or pre-processing facility, each waste supplier must prepare a representative sample. This must include a datasheet detailing the chemical and physical properties, information on relevant health, safety, and environmental considerations during transport, handling, and use of the material. It must also specify the source of the particular shipments being made;
- b) Test and check the sample's physical and chemical characteristics against specifications.

5.2 Assessment of possible impacts

When the cement plant operator and the pre-processing facility have received information about the waste, he must:

- a) Assess the potential impact of transporting, unloading, storing, and using the material on the health and safety of employees, contractors, and the

community. Ensure that equipment or management practices required to address these impacts are in place;

- b) Assess what personal protective equipment will be required for employees to safely handle the waste on site;
- c) Assess the compatibility of wastes; reactive or non-compatible wastes must not be mixed;
- d) Assess the effect the waste may have on the process operation. Chlorine, fluorine, sulphur, and alkali content in wastes may build up in the kiln system, leading to accumulation, clogging, and unstable operation; excess in chlorine or alkali may produce cement kiln dust or bypass dust (and may require installation of a bypass) which must be removed, recycled or disposed of responsibly. The heat value is the key parameter for the energy provided to the process. Wastes with high water content may reduce the productivity and efficiency of the kiln system and the ash content affects the chemical composition of the cement and may require an adjustment of the composition of the raw materials mix;
- e) Assess the potential impact on process stability and quality of the final product;
- f) Assess the effect the waste may have on plant emissions and whether new equipment or procedures are needed to ensure that there is no negative impact on the environment;
- g) Determine what materials analysis data the waste supplier will be required to provide with each delivery, and whether each load needs to be tested prior to off-loading at the site.

5.3 Commonly restricted wastes

Develop a uniform list of restricted wastes valid for the plant based on the previous impact assessment and the plants raw material and fuel composition. Certain cement companies choose not to treat the following wastes and materials:

- a) Electronic waste;

- b) Entire Batteries;
- c) Infectious and biological active medical waste;
- d) Mineral acids and corrosives;
- e) Explosives;
- f) Asbestos;
- g) Radioactive waste;
- h) Unsorted municipal waste;
- i) Unknown/unidentified wastes.

Individual companies may exclude additional materials depending on local circumstances and company policy.

Shipments crossing international boundaries and classified as hazardous waste under the Basel Convention must meet with the requirements of the Convention.

5.4 Check list for acceptance control

Delivered wastes must generally undergo specific admission controls, whereby the previously received declaration by the waste producer provides the starting point. After comparison by visual and analytical investigations with the data contained in the declaration, the waste is either accepted and allocated to the appropriate pre-processing and/or storage area, or rejected in the case of significant deviations.

Prior to signing any commercial contract, the cement plant operator must make sure that:

- a) The waste generator, collector, pre-processing facility provides adequate information on composition and risks of the material;
- b) They do not accept any substances, compounds or preparations which are not allowed or on the "negative list";
- c) They prohibit blending of incompatible materials and perform compatibility tests if needed;

- d) They perform sampling on the site of the generator, collector or the pre-processing facility and analysis before acceptance of commercial contracts. Sampling and analysis can be done by own or external, certified laboratories;
- e) They do not start transportation to plant site before completion of the acceptance process. This acceptance process does not replace sampling and analysis of waste deliveries at the plant sites;
- f) They communicate the inherent safety and health risks indicated by the waste generator, collector, pre-processor or identified by the sample analysis to the downstream operations (transport, pre- and co-processing) to ensure that PPE and installations are adapted accordingly;
- g) They provide simple, clear and practical handling procedures, based on the material properties, to each person who will work with the waste;
- h) They provide the commercial employees with adequate training in chemistry to allow them to enforce the waste acceptance criteria.

6 Waste collection and transport

Waste collection, handling and transport to the cement plant operator or the pre-processing facility must be effectively monitored, and be in full compliance with existing regulatory requirements; only qualified, authorised and licensed transport companies shall be used.

6.1 Waste collection and handling

The main concerns when handling wastes are human exposure, accidental release to the environment and contamination of other waste streams. Train staff in the correct methods of collecting and handling wastes. Handle wastes separately from other waste types in order to prevent contamination and recommended practices for this purpose include:

- a) Inspect drums and containers for leaks, holes, rust, and high temperature (handle wastes at temperatures below 25 °C, if possible, due to the increased volatility at higher temperatures);

- b) Ensure that spill containment measures is adequate and would contain liquid wastes if spilled;
- c) Place plastic sheeting or absorbent mats under containers before opening containers if the surface of the containment area is not coated with a smooth surface material (paint, urethane, epoxy);
- d) Remove liquid wastes either by removing the drain plug or by pumping with a peristaltic pump and Teflon or silicon tubing;
- e) Use dedicated pumps, tubing and drums, not used for any other purpose, to transfer liquid wastes;
- f) Clean up any spills with cloths, paper towels or absorbent;
- g) Triple rinse contaminated surfaces with a solvent such as kerosene to remove all of the residual wastes;
- h) Treat all absorbents and solvent from triple rinsing, disposable protective clothing and plastic sheeting as wastes.

6.2 Waste transport

Wastes consisting of, containing or contaminated with hazardous materials must be packaged prior to transport. Liquid wastes should be placed inter alia in double-bung steel drums (e.g. 16-gauge steel coated inside with epoxy). Containers used for storage should meet transport requirements in anticipation that they may be transported in the future.

Drums may be placed on pallets for movement by forklift truck and for storage, but must be strapped to the pallets prior to movement. All drums and containers must be clearly labelled with both a hazard-warning label and a label that gives the details of the drum, with its content, type of waste, and name and telephone number of the responsible person.

The pre-processing facility and cement plant operator must ensure that:

- a) Vehicles are fit for operation according to local regulations and waste specifications;

- b) Vehicles are clean (no spillage or residues);
- c) Drivers have received appropriate training in the transport of waste, including emergency response, based on local regulations (at a minimum).
- d) Drivers refuse to load and transport barrels, big bags or other waste packages, which are damaged, leaking or showing other conspicuous warning signs (e.g. barrel expansion from pressure build-up, elevated temperature etc.).

7 Waste reception and handling

Wastes received in drums at the pre-processing facility and cement plant must be packed, labelled and loaded properly to ensure that waste material reaches the plant in good condition. The transport of packed waste, typically waste in drums should present detailed instructions on the types of material. All wastes received at the plant should initially be treated as being unknown until compliance with specifications has been positively verified.

Vehicles carrying wastes must stop upon arrival and make the necessary identifications. Such vehicles should be:

- a) Weighed in and out of the site and deliveries must be recorded;
- b) Documents relating to vehicles carrying waste must be checked and the compliance with site acceptance specifications and regulations determined;
- c) Document checks should cover waste certificates, transport certificates, etc.;
- d) Instructions for unloading, including safety and emergency instructions, should be provided in due time to vehicle drivers.
- e) A vehicle found not to comply should not be allowed to enter the site.

7.1 Management for non-compliant deliveries

Written instructions must describe what to do in case of non-compliance with specifications and the waste producer must be informed about non-compliant deliveries. If non-compliance cannot be cleared with producer, the shipment must be rejected and if required in the permit, authorities must be notified.

Deliveries should be evaluated for each waste producer on a statistical basis in order to assess the performance and reliability of the producers; periodically review contracts accordingly.

7.2 Checking, sampling and testing incoming wastes – general considerations

Delivered wastes must undergo specific admission controls, whereby the previously received declaration by the waste producer provides the starting point. Sample and analyze vehicle loads once on site according to the frequency and protocol defined in the site control plan; check agreement with site specifications according to the plan of control. Accept wastes once their properties are confirmed to agree with specifications.

7.2.1 Assess incoming wastes

Apply a suitable regime for the assessment of incoming waste. Such assessment must reveal:

- a) That the wastes received are within the range suitable for the installation;
- b) Whether the wastes need special handling/storage/treatment/removal for off-site transfer;
- c) Whether the wastes are as described by the supplier (for contractual, operational or legal reasons).

7.2.2 Techniques for checking

Techniques for checking vary from simple visual assessment to full chemical analysis. The extent of the procedures adopted will depend upon:

- a) Nature and composition of waste;
- b) Heterogeneity of the waste;
- c) Known difficulties with wastes (of a certain type or from a certain source);
- d) Specific sensitivities of the installation concerned (e.g. certain substances known to cause operational difficulties);
- e) Whether the waste is of a known or unknown origin (should be avoided);
- f) Existence or absence of a quality controlled specification for the waste;
- g) Whether the wastes have been dealt with before and the plants experiences with it.

7.2.3 Inspection

Apply the following inspection scheme:

- a) Control and comparison of data in the declaration list in comparison with delivered waste;
- b) Sampling and analysis of all bulk tankers;
- c) Random checking of drummed loads;
- d) Unpacking and checking of packaged loads;
- e) Assessment of combustion parameters;
- f) Blending tests on liquid wastes prior to storage;
- g) Control of flashpoint for wastes in the bunker;

- h) Screening of waste input for elemental composition e.g. by XRF and/or other appropriate techniques.

7.3 Reception and handling

There should be written procedures and instructions in place for the unloading, handling, and storage of the solid and liquid wastes used on site, i.e.:

- a) Designated routes for vehicles carrying specified wastes should be clearly identified within the site;
- b) Relevant employees should be trained in the company's operating procedures, and compliance with such procedures should be audited regularly;
- c) Appropriate signs indicating the nature of wastes should be in place at storage, stockpiling, and tank locations;
- d) Storage facilities should be operated in such a way as to control emissions to air, water, and soil.

7.3.1 Labelling

In general, waste delivery is accompanied by a suitable description of the waste; an appropriate assessment of this description and the waste itself forms a basic part of waste quality control. An indicative list of the most important parameters for labelling includes:

- a) Name and address of the deliverer;
- b) Origin of the waste;
- c) Volume;
- d) Water and ash content;
- e) Calorific value;
- f) Concentration of chlorides, fluorides, sulphur and heavy metals.

8 Waste pre-processing

The use of wastes must not detract from smooth and continuous cement kiln operation, product quality, or the site's normal environmental performance implying that wastes used in cement kilns must be homogenous and have a stable chemical composition and heat content, and a pre-specified size distribution. Pre-processing and preparation with the objective of providing a more homogeneous feed and more stable combustion conditions may therefore be necessary.

Such pre-processing can include drying, shredding, grinding or mixing depending on the type of waste. Pre-processing is usually done in a purpose made facility, which may be located outside or inside the cement plant. If the alternative fuel is prepared outside the cement plant, the fuels only need to be stored at the cement plant and then proportioned for feeding them to the cement kiln.

8.1 Alternative fuels

Alternative fuels can be subdivided into five classes:

1. Gaseous alternative fuels, for example coke oven gases, refinery waste gas, pyrolysis gas, landfill gas, etc.
2. Liquid alternative fuels, for example low chlorine spent solvents, lubricating as well as vegetable oils and fats, distillation residues, hydraulic oils, insulating oils, etc. Some equipment can be sealed under a nitrogen blanket to reduce fire and explosion risks when handling liquids.
3. Pulverized, granulated or fine crushed solid alternative fuels, for example ground waste wood, sawdust, planer shavings, dried sewage sludge, granulated plastic, animal flours, agricultural residues, residues from food production, fine crushed tyres, etc.
4. Coarse crushed solid alternative fuels, for example crushed tyres, rubber/plastic waste, waste wood, re-agglomerated organic matter, etc.
5. Lump alternative fuels, for example whole tyres, plastic bales, material in bags and drums, etc.

Mixing and homogenisation of wastes will generally improve feeding and combustion behaviour. Mixing of wastes can involve risks and should be carried out according to a prescribed recipe.

8.2 Pre-processing and mixing of alternative fuels

Techniques used for waste pre-processing and mixing are wide ranging, and may include:

- a) Mixing and homogenising of liquid wastes to meet input requirements, e.g. viscosity, composition and/or heat content;
- b) Shredding, crushing, and shearing of packaged wastes and bulky combustible wastes, e.g. tyres;
- c) Mixing of wastes in a bunker using a grab or other machine (e.g. sprelling machines for sewage sludge);
- d) Production of refuse derived fuel (RDF), usually produced from source separated waste and/or other wastes.

Solid heterogeneous wastes can be mixed in a bunker or a pit prior to loading into transport or feed systems. In bunkers, the mixing involves blending of wastes using cranes and the crane operators can identify potentially problematic loads (e.g. baled wastes, discrete items that cannot be mixed or will cause loading/feeding problems) and ensure that these are removed, shredded or directly blended (as appropriate) with other wastes. Crane capacity must be sufficient to allow mixing and loading at a suitable rate.

8.3 Segregation of waste types for safe processing

Waste acceptance procedures and storage depend on the chemical and physical characteristics of the waste. Appropriate waste assessment is an essential element in the selection of storage and input operations and is strongly related to the checking, sampling and assessment of incoming wastes.

The segregation techniques applied vary according to the type of wastes received at the plant. Segregation relates to maintaining separation of materials to avoid hazardous mixtures. Extensive procedures are required to separate chemically incompatible materials.

Proper labelling of the wastes (e.g. in accordance with the European Waste Catalogue) that is delivered in containers, assists their identification and traceability, and ensures:

- a) Knowledge of waste content, which is required for choice of handling/processing operations;
- b) The operators ability to trace sources of problems and then to take steps to eliminate or control them;
- c) The ability to demonstrate conformance with restrictions on waste types and quantities received/processed.

Bar code systems and scan readers can be used for packaged and liquid wastes. The costs of such systems are low in relation to the benefits.

8.4 General design considerations

Carefully consider the cement plant and the pre-processing facility layout to ensure access for day-to-day operations, emergency escape routes, and maintainability of the plant and equipment.

Apply recognized standards to the design of installations and equipment. Any modification to installations and equipment should meet requirements set in the standards. Thoroughly evaluate existing equipment refitted for a different service from a safety and performance standpoint before resuming commercial production. Document any modifications to installations and equipment.

Assess operations for health and safety risks or concerns to ensure that equipment is safe and to minimize risks of endangering people or installations, or damaging the environment. Use appropriate procedures to assess risks or hazards for each stage of the design process. Only competent and qualified personnel should undertake or oversee such hazard and operability studies.

8.4.1 Design for reception and storage of wastes

Establish suitable and safe transfer systems from transportation to the storage area to avoid risks from spillage, fugitive emissions or vapour. Suitable vapour filtration and capture equipment should be in place to minimize impact to the reception point and surrounding areas from unloading activities.

Transfer and storage areas must be designed to manage and contain accidental spills into rainwater or firewater, which may be contaminated by the materials. This requires appropriate design for isolation, containment, and treatment as follows:

- a) All ground area within diked, storage areas must be sealed so that spills will not penetrate the ground;
- b) Sealed concrete surfaces with well controlled drainage are recommended;
- c) All leaks, spills, rainwater etc. should be easily collected and saved for destruction;
- d) No runoff water from the waste chemical storage area should be discharged to sewers. Any such runoff should be redirected into storage tank for subsequent high temperature destruction in the kiln;
- e) Leak free design should be specified whenever possible;
- f) Methods to contain and recover piping leaks without environmental contamination should be provided;
- g) Adequate alarms for abnormal conditions should be provided.

Monitoring systems capable of detecting volatile organic vapours should be placed at key process locations to signal accidental waste fuel leaks. Periodic monitoring for volatile organic compound emissions should be provided.

All volatile organic emissions from waste storage and pre-processing facilities could be exhausted to the cement kiln for complete destruction. Alternatively, a closed vapour line between the storage tank vents and the tank trucks should be provided to return the displaced volatile organic vapours from the storage tanks to the tank truck, when loading the tanks.

A back up carbon adsorption vapour control system could be provided to control volatile organic compound storage tank breathing emissions. Explosion proof safety valves should be used.

8.4.2 Housekeeping

General tidiness and cleanliness contribute to an enhanced working environment and can allow potential operational problems to be identified in advance. The main elements of good housekeeping are:

- a) The use of systems to identify and locate/store wastes received according to their risks;
- b) The prevention of dust emissions from operating equipment;
- c) Effective waste water management;
- d) Effective preventive maintenance.

9 Waste storage

Limit waste volumes in storage and waste storage time to a minimum, i.e. maximum allowed waste storage should be determined on the installed fire protection systems, which should include early warning sensors like temperature and smoke detectors.

Define limits for waste and processed wastes storage times per type of material in the permit, taking into consideration the corresponding health and safety risks (toxicity, reactivity, flammability/explosion potential, and storage conditions) and local regulations.

Assure that storage facilities fit their purpose. In general, the storage of wastes needs, additionally, to take into account the unknown nature and composition of wastes, as this gives rise to additional risks and uncertainties. In many cases, this uncertainty means that higher specification storage systems are applied for wastes than for well-characterised raw materials.

A common practice is to ensure, as far as possible, that wastes are stored in the same containers (drums) that are used for transport; thus avoiding the need for additional handling and transfer.

Good communication between the waste producer and the waste manager help to ensure wastes are stored and transferred, etc., such that risks all along the chain are well managed. It is also important that only well characterised and compatible wastes are stored in tanks or bunkers.

9.1 Liquid and solid wastes

Appropriate waste assessment is an essential element in the selection of storage and loading options. Some issues to note are:

- a) For the storage of solid waste, many plants are equipped with a bunker from where the waste is fed into the installation by cranes or feed hoppers;
- b) Liquid wastes and sludge's, these are usually stored in a tank farm. Some tanks have storage under an inert (e.g. N₂) atmosphere. Liquid waste may be pumped via pipelines to the kiln. Sludge's can be fed by using special "viscous-matter" pumps. Appropriate storage for liquids should meet relevant safety and design codes for storage pressures and temperatures and should have adequate secondary containment;
- c) Some kilns are able to feed certain substances, such as toxic, odorous liquids, by means of a direct injection device, directly from the transport container into the kiln.

Wastes should be stored in an isolated area, preferable well fenced and locked, to provide good security from intruders and vandals. Incompatible wastes must be kept separate. The waste liquid storage sump area should be enclosed and all vent gases from such area and storage tank should be vented to an emission control system. Solid materials handling systems should have adequate dust control systems.

9.2 Storage time

Storage design should be appropriate to maintain the quality and storage time of the materials. The design should prevent build-up of old materials for solids and apply mixing or agitation to prevent settlements in liquids.

Storage of wastes should be for as brief a period as possible and in accordance with the permit and regulation. Recommended maximum storage times are:

- a) 10 days for waste mixtures, and wastes;
- b) 21 days for waste impregnated substrates;
- c) For non- AFR, storage time is limited by the designed storage capacity and installed fire suppression systems.

9.3 Storage of solid waste

Solid and un-pumpable pasty waste that has been degassed and does not smell can be stored temporarily in bunkers. Storage and mixing areas can be separated in the bunker. This can be achieved through several design segments. The bunker must be designed in such a way that ground emissions can be prevented.

The bunker and container storage must be enclosed unless health and safety reasons (danger of explosion and fire) exist. The air in the bunker may be removed and ducted to the kiln. In anticipating fires, monitors such as heat-detecting cameras are used, in addition to constant monitoring by personnel (control room, operator).

9.3.1 Storage of pumpable waste

Larger amounts of fluid and pumpable pasty wastes are temporarily stored in tanks that must be available in sufficient numbers and sizes to accommodate reacting liquids separately (danger of explosion, polymerisation).

Tanks, pipelines, valves, and seals must be adapted to the waste characteristics in terms of construction, material selection, and design. They must be sufficiently corrosion-proof, and offer the option of cleaning and sampling. Flat bed tanks are generally only deployed for large loads.

It may be necessary to homogenise the tank contents with mechanical or hydraulic agitators. Depending on the waste characteristics, some tanks must be heated indirectly and insulated. Tanks are set in catch basins that must be designed for the stored material, with bund volumes chosen so that they can hold the liquid waste in the event of leakage.

9.4 Storage for containers and tank containers

For safety reasons, waste is often accumulated in special containers, which can be delivered directly to the plant. Delivery is also taken of bulk liquids.

The delivered containers may be stored or the contents transferred. In some cases, according to a risk assessment, the waste may be directly injected via a separate pipeline into the kiln. Heated transfer lines may be used for wastes that are only liquid at higher temperatures.

Storage areas for containers and tank containers are usually located outside, with or without roofs. Drainage from these areas is generally controlled, as contamination may arise.

9.5 Safety aspects of storage

The following measures will strengthen safety:

- a) Storage areas should be kept clear of uncontrolled combustible materials;
- b) Clear safety warnings, no smoking, fire, evacuation route, and any procedures signs should be clearly posted;
- c) An emergency shower and eye washing station should be clearly marked and located near the storage of liquid alternative fuels;
- d) A fire protection system must be available at all times and should meet all standards and specifications from local authorities (e.g. local fire department);

- e) Adequate alarms should be provided to alert all personnel about emergency situations;
- f) Communications equipment should be maintained at the site so that the control room and the local fire department can be contacted immediately in case of a fire;
- g) Equipment should be grounded and appropriate anti-static devices and adequate electrical devices selected (e.g. motors, instruments, etc.).

9.5.1 The use of fire detection and control systems

Automatic fire detection systems should be used in waste storage areas as well as for fabric and static filters, electrical and control rooms, and other identified risk areas.

Automatic fire control systems should be applied in some cases, most commonly when storing flammable liquid waste although also in other risk areas.

Foam and carbon dioxide control systems provide advantages in some circumstances e.g. for the storage of flammable liquids. Foam nozzles are commonly used in MSW incineration plants in the waste storage bunker. Water systems with monitors, water cannons with the option to use water or foam, and dry powder systems are also used.

Nitrogen blanketing may be used in fixed coke filters, fabric filters, tank farms, or for the pre-treatment and kiln loading facilities for wastes.

Continuous automatic measurement of temperature can be carried out on the surface of wastes stored in the bunkers. Temperature variations can be used to trigger an acoustic alarm. There are also other safety devices, such as:

- a) Nozzles above the waste feed hoppers;
- b) Fire resistant walls to separate transformers and retention devices under transformers;
- c) Gas detection above gas distribution module.

When ammonia is used, its storage requires specific safety measures, i.e. NH₃ detection and water spray devices to absorb releases.

10 Best available techniques and best environmental practise (BAT/BEP)

Technological advancement of the cement industry will concentrate on the further development of new technology, on the utilization of secondary materials and other supplementary cementitious materials. In recent years, improvement of cement production lines with pre-calcining systems includes the new homogenization technology, new preheating and pre-calcining systems with the capacity of up to ten thousand tons of cement per day, various new types of crushing and grinding systems, new operation and management systems, new environmental protection measures such as the use of new bag dust collector and low NO_x burner. The utilization of secondary materials and supplementary cementitious materials may save huge amounts of natural resources.

10.1 BAT/BEP for cement production

Dry preheater/precalciner kilns are regarded to be the best available techniques (BAT) and to constitute the Best Environmental Practise (BEP). These technologies are also the most economically feasible option, which constitutes a competitive advantage and thereby contributes to gradually phase out older, polluting and less competitive technologies.

For new plants and major upgrades the best available techniques for the production of cement clinker is a dry process kiln with multi-stage preheating and precalcination. A smooth and stable kiln process, operating close to the process parameter set points, is beneficial for all kiln emissions as well as the energy use. This can be obtained by applying:

- Process control optimisation, including computer-based automatic control systems;
- The use of modern fuel feed systems;

- Minimising fuel energy use by means of preheating and precalcination to the extent possible, considering the existing kiln system configuration.

Careful selection and control of substances entering the kiln can reduce emissions and when practicable, homogenous raw materials and fuels with low contents of sulfur, nitrogen, chlorine, metals and volatile organic compounds should be selected.

10.2 Fuels feeding

Three different types of conventional or fossil fuels are used in cement kiln firing in decreasing order of importance:

- Pulverized coal and petcoke;
- Fuel oil (heavy);
- Natural gas.

In order to keep heat losses at minimum, cement kilns are operated at lowest reasonable excess oxygen factors. This requires highly uniform and reliable fuel metering as well as the fuel being present in a form which allows for easy and complete combustion (fuel preparation process and fuel storage). These conditions are fulfilled by all pulverized, liquid and gaseous fuels, be it conventional or alternative fuels. The main fuel input (65 – 85%) has therefore to be of this type whereas the remaining 15 – 35% may be fed in coarse crushed or lumpy form.

Fuel feed points to the cement kiln system are via the:

- Main burner at the rotary kiln outlet end;
- Feed chute at the transition chamber at the rotary kiln inlet end (for lump fuel);
- Fuel burners to the riser duct;
- Precalciner burners to the precalciner;
- Feed chute to the precalciner (for lump fuel);

- Mid-kiln valve to long wet and dry kilns (for lump fuel).

The fuel introduced via the main burner to the hot zone of the rotary kiln therein produces the main flame with flame temperatures around 2000° C. For process optimisation reasons the flame has to be adjustable within limits. The flame is shaped and adjusted by the so-called primary air (10 – 15% of total combustion air) through interaction of the outer axial air ring channel as well as of the conical inner air ring channel of the (main) burner.

11 Co-processing of alternative fuels

Conventional fuels are today increasingly substituted by non-conventional, non-fossil (gaseous, liquid, pulverized, coarse crushed) alternative (or secondary) fuels for resource efficiency and economic reasons.

Many regulations do not restrict the use of wastes to certain categories or concentration limits; some focus on emissions limits only. Other regulations specify an explicit list of acceptable AFRs with maximum and/or minimum values for various parameters, e.g. heavy metals, chlorine, calorific value etc. called the “positive” list and some regulations specify a negative list with waste categories not allowed. Independent of concept chosen, it will be the local raw material and fuel chemistry, the infrastructure and the cement production process, the availability of equipment for controlling, handling and feeding the waste materials, and finally site specific health, safety and environmental issues which determines the waste categories to be accepted at the specific plant.

11.1 Input control – general rules

Use wastes only after the supplier, the chemical and physical properties and specifications of the materials have been clearly identified.

Consistent long-term supply of appropriate waste is required to maintain stable conditions during operation. Content of sulphur, nitrogen, chlorine, fluorine, metals and volatile organic compounds needs to be specified and carefully controlled. Limitations with respect to the product and/or the process should be established.

Feeding of waste to the kiln must ensure exposure to:

- a) Sufficient temperature;
- b) Sufficient retention time;
- c) Sufficient mixing conditions;
- d) Sufficient oxygen.

The waste type and composition will determine the adequate feeding point; i.e. the main burner or the secondary burner in precalciner/preheater will ensure temperature > 900 °C. No waste should be fed as part of raw mix feed if it contains organics, and no waste feed during start-up and shutdown.

Handling and feed systems should be appropriate to the waste used and must ensure stable and controlled input to the kiln. The operator should assess risks from fugitive emissions; equipment failure modes and appropriate safeguards should be incorporated into the design to prevent environmental pollution, health, and safety problems.

Automated monitors should be employed to alert operators in the event of a waste handling problem. A pressure transducer located in the waste piping at the entrance of the kiln should be provided to turn off the waste fuel pump automatically in the event of a sudden pressure drop due to pipe rupture or pump failure.

Interlocks should be provided to stop the flow of waste automatically if either normal fuel or feed supply or combustion airflow is interrupted (fans stopped or reduced), or if carbon monoxide levels indicate problems with combustion efficiency.

11.2 Selection of feed point

The use of AFRs should not detract from smooth and continuous kiln operation, product quality, or the site's normal environmental performance. Therefore, a constant quality and feed rate of the waste materials must be ensured.

The feed point for wastes into the kiln should be selected according to the nature (and, if relevant, hazardous characteristics) of the wastes used. Gaseous, liquid,

and finely pulverized alternative fuels can be fed to the kiln system via any of the feed points mentioned in the previous chapter. Coarse crushed and lump fuels can be fed to the transition chamber or to the mid-kiln valve only (with some exceptions). Hazardous wastes should be introduced in the high-temperature combustion zone of the kiln system, i.e. the main burner, the precalciner burner, the secondary firing at the preheater, or the mid-kiln (for long dry and wet kilns).

The following is valid:

- a) Persistent organic pollutants and highly chlorinated organic compounds should be introduced at the main burner to ensure complete combustion due to the high combustion temperature and long retention time. Other feed points are appropriate only where test have shown high destruction and removal efficiency rates;
- b) Alternative raw materials with volatile organic components should not be introduced with other raw materials in the process, unless tests have shown that undesired emissions at the stack do not occur; such raw materials can be fed through a double or triple flap arrangement into the kiln inlet;
- c) Mineral inorganic wastes free of organic compounds can be added to the raw meal or raw slurry preparation system. Mineral wastes containing significantly quantities of organic components are introduced via the solid fuels handling system, i.e. directly to the main burner, to the secondary firing or, rarely, to the calcining zone of long wet or dry kilns;
- d) Mineral additions such as granulated blast furnace slag, fly ash from thermal power plants or industrial gypsum can be fed to the cement mill.

11.3 Operations and process control

Operating requirements should be developed to specify the acceptable composition of the waste feed, including acceptable variations in the physical and/or chemical properties of the waste. For each waste, the operating requirements should specify acceptable operating limits for feed rates, temperatures, retention time, oxygen etc.

For start-up, shutdown, or upset conditions of the kiln, written instructions should be issued, describing conditions of use of wastes. Kiln operators should know and understand these instructions.

The general principle of good operational control of the kiln system using conventional fuels and raw materials should be applied. In particular, all relevant process parameters should be measured, recorded and evaluated continuously and may cover:

- a) Free lime;
- b) Oxygen concentration;
- c) Carbon monoxide concentration.

11.3.1 Kiln operation and feeding of wastes

The plant should characterize a good operation and use this as a basis to improve other operational performance.

Having characterized a good and stable kiln, establish reference data by adding controlled doses of waste, and look at changes and required controls and practice to control emissions. The impact of wastes on the total input of circulating volatile elements such as chlorine, sulphur, or alkalis must be assessed carefully prior to acceptance as they may cause operational troubles in the kiln system.

The kiln process must be operated to achieve stable conditions, which may be achieved by applying process control optimization (including computer-based automatic control systems) and use of modern, gravimetric solid fuel feed systems.

Input limits and operational set points for these components should be set individually by the site based on the process type and on the specific site conditions.

Procedures for stopping waste feed in the event of an equipment malfunction or other emergency must be implemented and the set points for each operating parameter that would activate feed cut-off must be specified. The waste feed must also be cut off when operating conditions deviate from limits established in the permit.

No waste burning should take place unless the cement kiln is operating at normal temperatures in the range of 1100 °C to 1600 °C and instrumentation must be provided to record continuously the rate of flow of these wastes.

Feeding of wastes should not be permitted during periods of kiln start-up, shut-down, major upset or conventional (coal) fuel interruption.

Kiln coating temperature should be measured by a recording optical pyrometer and conventional (coal) fuel flow should be continuously measured and recorded.

Examples of system controls and set points, which could provide for automatic shutdown of introduction of wastes in the event any of the following conditions occur:

- a) Cement kiln temperatures fall below 1100 °C;
- b) Conventional raw meal and fuel flow interruption;
- c) Kiln speed decrease to below 60 RPH;
- d) Loss of draft in the firing hood and main fan stoppage;
- e) The kiln should be operated at all times in an oxidizing atmosphere. Oxygen in the kiln exhaust gases must be maintained at a level of not less than 1.5% and be continuously recorded;
- f) If the outside skin temperature of the kiln exceeds 500 °C, the feed of wastes should be stopped and shutdown should be initiated for repair of the refractory. Reintroduction of wastes should not take place until such lining repairs are completed;
- g) Waste introduction into the kiln should cease in the event of kiln ring formation;
- h) Wastes must not be used during failure of the air pollution control devices. The kiln exhaust gases must be quickly conditioned and cooled the lower than 200 °C to avoid formation and release of dioxins and other POPs;
- i) Fugitive emissions must be prevented and controlled and the off-gas dust from the filters should be fed back into the kiln to the maximum extent

practicable, in order to reduce issues related to treatment and emissions. Dust that cannot be recycled should be managed in a manner demonstrated to be safe.

11.4 Feeding of waste fuel at Vorkuta cement plant

In the wet process the raw material is blended with water to produce slurry (30 to 40% moisture content) which is pumped directly into the cold end of the kiln, i.e. the kiln inlet. The scurrying process helps homogenize the raw materials prior to feeding to the kiln. The wet process is the oldest and most energy intensive production process, because the water must be evaporated out of the raw material slurry mixture. Feeding alternative fuels to wet kilns makes economic sense as cost (or fuel cost) of clinker production is high compared to modern dry processes. Specific heat consumption of wet process ranges from 5.9 to 6.7 GJ/ t of clinker which is almost double than modern dry process pre-heater pre-calciner kilns.

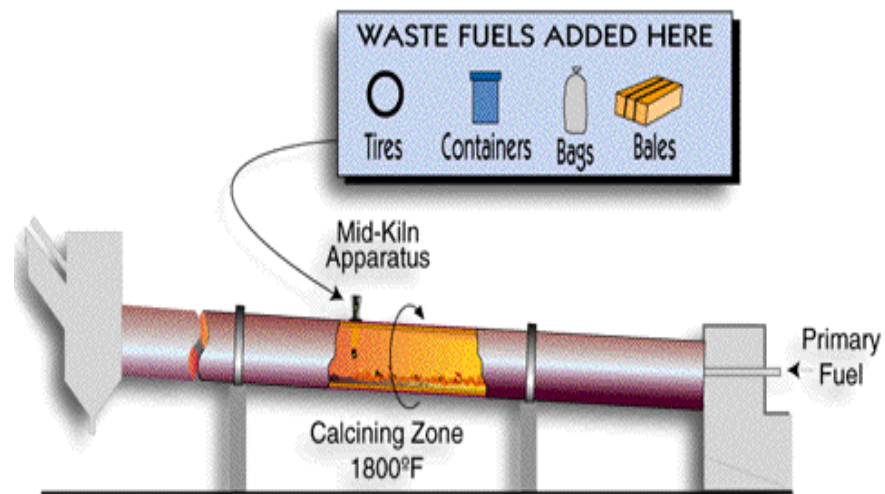


Figure 7 Feeding of wastes to a wet kiln

The recommended feeding points for alternative fuels in wet kilns are either at the kiln outlet or mid-kiln. At the kiln outlet, fine size reduced waste materials can be fed through the main burner together with coal, or through a separate injection point in parallel to the main burner. At the mid-kiln, lump waste materials can be fed as alternative fuels through a mid-kiln valve, typically tyres.

Waste materials containing organic components should never be fed to the kiln inlet or together with raw material slurry, as these organic compounds will be evaporated into the exhaust gas and may act as precursors for dioxin formation in

the electro static precipitator. The exhaust gas should also be quenched or cooled rapidly to a temperature lower than 200 °C prior to entering into electro static precipitator to avoid dioxin formation.

Vorkuta cement plant is manually feeding whole wood sleepers and shredded/cut tyres at the kiln outlet in parallel with the coal main firing at a thermal substitution rate of 5-10%. Due to high temperature and long residence time inside the kiln, complete burnout and no influence on dioxin formation can be expected.

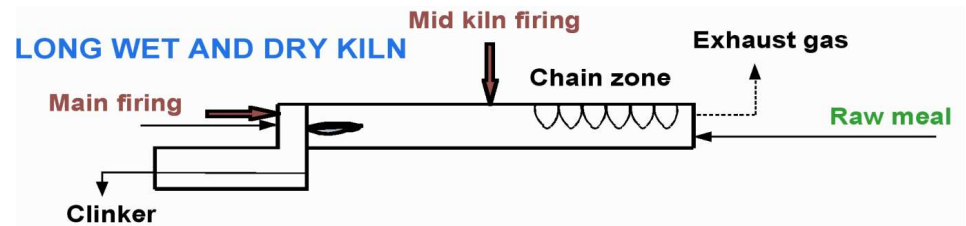


Figure 8 Long wet and dry kiln

11.5 Laboratory and quality control

The plant needs an adequate laboratory, with sufficient infrastructure, sampling equipment, instrumentation and test equipment. Inter-laboratory tests should be carried out periodically in order to check and improve the performances and maintenance of the laboratory. Personnel must be competent and should be trained according to their specific needs and to the nature of the AFR or wastes used.

Fuels, raw materials, and any AFRs or wastes entering, being processed or produced at the site, should be controlled regularly. A plan should provide detailed instructions for:

- a) Personnel assignment;
- b) Sampling;
- c) Frequency of sampling and analysis;
- d) Laboratory protocols and standards;
- e) Calibration procedures and maintenance;
- f) Recording and reporting protocol.

12 Cement quality

The cement plant must carry out chemical and physical analysis for all relevant parameters concerning cement quality and potential clinker contamination on a routine basis and all data must be kept recorded.

Co-processing of AFRs shall not affect the cement quality and this must be documented. The operator must be aware that fluorine, phosphate and zinc influences setting time and strength development of the cement, that chlorine, sulphur and alkalis affect overall product quality and that chromium may cause allergic reactions in sensitive users.

The classification of cements in terms of their strength-giving properties has been practised for many years. It is impractical for cement producers to test the cements they make with all the many different sands and aggregates and in the wide range of mix proportions they are likely to meet in practice. Standard test procedures have therefore been developed to enable manufacturers to control their production. The strength-giving characteristics of cements can take the form of assessments at early (2- 3 days) or late (28 days) ages or both. The European ENV 197-1 places primary emphasis upon the 28-day strength and for this purpose introduces three classes, 32.5, 42.5 and 52.5 representing the minimum characteristic strength, in N/mm², which the cement is required to achieve at 28 days from tests made in accordance with the test method described in European Standard EN 196-1.

13 Emission monitoring

Emission monitoring is obligatory in order to demonstrate compliance with existing laws, regulations, and agreements. Emission monitoring is also needed for controlling the input of conventional materials and their potential impacts. Sulphides in raw materials may result in the release of SO₂ and organic carbon in raw materials will result in CO, CO₂ and volatile organic compound (VOC) emissions. Heavy metals in fuel and raw material, especially volatile heavy metals, which are not completely captured in the clinker, must be assessed, monitored and controlled.

13.1 Emission limit values for cement kilns in Europe

For emissions to air, cement kilns co-processing AFR and treating wastes in the EU must comply with the Directive 2000/76/EC and must meet the emissions limits in flue gases given in table 2 below, corrected to 273 K, 101.3 kPa, 10% O₂ and dry gas.

Table 2 Daily average values for cement plants co-incineration of waste (less than 40% of the resulting heat release must come from waste), at 10% O₂, dry gas; all values in mg/m³; dioxins and furans in ng/m³.

Pollutant	C
Total dust	30
HCl	10
HF	1
NO _x	500 ¹⁾ /800 ²⁾
Cd + Tl	0.05
Hg	0.05
Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V	0.5
Dioxins and furans	0.1
SO ₂	50 ³⁾
TOC	10 ³⁾

1) new plants 2) existing plants 3) exceptions may be authorized by the component authority in cases where SO₂ and TOC do not result from the waste.

13.2 Continuous emission measurements

To monitor the process and accurately quantify the emissions, continuous emission measurements are recommended for the following parameters:

- a) Exhaust volume;
- b) Humidity;
- c) Temperatures;
- d) Particulate matter;
- e) O₂;
- f) NO_x;
- g) SO₂;
- h) CO;
- i) Volatile organic compounds (VOC);

- j) HCl;
- k) Pressure.

13.3 Regular monitoring

Periodical monitoring should be conducted for the following substances on a regular basis:

- a) Metals and their compounds;
- b) Total organic carbon;
- c) HF;
- d) NH₃;
- e) PCDD/PCDF;
- f) Chlorobenzenes, HCB and PCBs including coplanar congeners and chloronaphthalenes.

13.4 Occasional monitoring

Measurements of the following substances may be required occasionally under special operating conditions:

- a) Demonstration of the destruction and removal efficiency (DRE) and the destruction efficiency (DE);
- b) Benzene, toluene and xylene;
- c) Polycyclic aromatic hydrocarbons;
- d) Other organic pollutants.

It is especially important to measure metals when wastes with higher metal content are used as raw materials or fuels.

13.5 Additional measures for exit gas cleaning

Activated carbon filter has high removal efficiency for trace pollutants (> 90%). Pollutants such as sulphur dioxide (SO₂), organic compounds, metals, ammonia (NH₃), ammonium (NH₄⁺) compounds, hydrogen chloride (HCl), hydrogen fluoride (HF) and residual dust may also be removed from the exhaust gases by adsorption on activated carbon.

Selective catalytic reduction can be applied for NO_x control. The process reduces NO and NO₂ to N₂ with the help of NH₃ and a catalyst at a temperature range of about 300 ° - 400 °C, which imply heating of the exhaust gases.

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Appendix 3 Fact sheet - best practice for PCDD/PCDF monitoring/control in EU countries

Legal requirements

For industries considered major sources of PCDD/PCDF² emission, emission limit values have been established in the European Union (EU).

Directive 2000/76/EC on incineration of waste establishes an emission limit value for waste incinerators and waste co-incineration plants (including cement kilns co-incinerating waste) at 0.1 ng TEQ/Nm³. The toxicity equivalency (TEQ) is calculated as a total of 17 measured congeners. The toxicity equivalency of each of the 17 individual PCDD/PCBF congeners is estimated using congener-specific equivalence factors (TEF) defined in the directive. The system is known as the International toxicity equivalence system and the toxicity equivalency is often expressed as I-TEQ. The concentration is standardised to certain standard conditions with respect to temperature, pressure, gas humidity and oxygen concentration.

For other industrial activities, Directive 2010/75/EU on industrial emissions (EID) is the main EU instrument regulating PCDD/PCDF emissions from industrial installations. The permit conditions for the installations, including emission limit values, are based on the Best Available Techniques (BAT). In order to define BAT and the BAT-associated environmental performance at EU level, a number of BAT Reference Documents (BREFs) have been developed for various industrial sectors. The BAT conclusions contained in the BREFs are to be adopted by the European Commission as Implementing Decisions - a process which is currently ongoing. The IED requires that the BAT conclusions are the reference for setting permit conditions. For industries that are considered potential sources of PCDD/PCDF emissions, including installations in the ferrous and non-ferrous sectors and cement plants, limit values are established in the BREFs. In general, the applied limit value is 0.1 ng TEQ/Nm³ defined in the same way as in the Directive 2000/76/EC.

The emission limits are defined as the PCDD/PCDF concentration in the flue gas whereas none of the directives established limits in terms of total annual PCDD/PCDF emission from an installation.

Standard for PCDD/PCDF determination

Sampling and analysis of PCDD/PCDF as well as reference measurement methods to calibrate automated measurement systems shall be carried out in accordance with European CEN-standards. Sampling procedures are established in EN 1948-1, while analytical procedures are described in EN 1948-2 and the identification and quantification of PCDDs/PCDFs are established in EN 1948-3.

The methods defined in EN 1948 are by and large similar to the Russian standard PND F 13.1.65-08 "*Methods of measurement of the total content polychlorinated*

² PCDD/PCDF = polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans

dibenzo-p-dioxins and dibenzofurans based on 2,3,7,8-tetrachlorodibenzo-p-dioxin in samples of industrial emissions into the atmosphere by chromatography-mass spectrometry". The Russian standard uses the same toxicity equivalency factors as Directive 2000/76/EC (I-TEQ).

Monitoring frequency

Directive 2000/76/EC defines that at least two measurements per year of PCDD/PCDF emission shall be carried out; however during the first 12 months of operation, measurement shall be carried out at least every three months. A reduction of the frequency of the periodic measurements of PCDD/PCDF from twice a year to once every year may be authorised in the permit by the competent authority provided that the emissions resulting from co-incineration or incineration are below 50% of the emission limit values and provided criteria for the requirements to be met are available.

The BREFs do in general not define monitoring frequency and the monitoring frequency for PCDD/PCDF from installations other than the installations targeted by Directive 2000/76/EC varies among Member States and industries. The BREF for the iron and steel industry e.g. lists the monitoring frequencies in various Member States for different types of installations. The frequency varies from once every month for sinter plants in Belgium to once every three years for iron and steel plants in Austria. The frequency is determined by either national or local competent authorities and reflects variations in emission from the sources and how far the measured PCDD/PCDF emission is below the established limit value.

Duration and number of samples

Neither the two directives nor the standard EN-1948 defines exactly the sampling time or the number of samples to be taken. The EN 1948-1, defines that the sampling time should not exceed 8 hours.

The duration and number of samples may be defined by national guidelines. As an example, the Danish guidelines for PCDD/PCDF emission from industrial installations requires that at least two samples are taken which are each analysed (i.e. at least double determination). The arithmetic mean of all measurements is used in determining whether the emission is below the limit value. The measurements can either be based on simultaneous sampling (with two sampling probes at the same time) or sequential sampling (typical two samples of about 6 hours in sequence). The sequential sampling gives most information on the variation in the concentration and may be preferable in installations with variation in raw materials and fuels, whereas the simultaneous sampling gives a better indication of the uncertainty on the sampling/analysis and is less expensive as it takes less time. The Danish guidelines recommend that the sampling time is 6 hours the first times dioxin is measured in an installation in order not to be too sensitive to short-term variations in the concentrations. Later, the sampling time may be reduced to about 2 hours.

MEMO

TITLE Review the "Assessment of the Barents Hot Spot Report" with regard to dioxins issues
DATE 30 January 2015
TO NEFCO, ACAP Steering Group for dioxins
COPY
FROM Carsten Lassen, COWI
PROJECT NO

Appendix 4 Review of the Barents Hot Spot list

This note include a short review of the report "Assessment of the Barents Hot Spot Report – Describing the state of 42 original Barents environmental ‘hot spots’ (Ak-vaplán-NIVA for NEFCO, 30 May 2013)" with regard to the potential dioxin (PCDD/F) projects or other initiatives to be addressed by the ACAP PSG.

According to the Terms of Reference, for those “Hot Spots” identified with such a potential the corresponding “screening & analyses” (S&A) should be reviewed and commented (to be provided via the BEAC WGE Subgroup on Hot spot Exclusion (SHE)).

This draft note include the first review and will be revised when S&A reports for the relevant Hot Spots have been assessed.

The main background for the review of the Hot Spot list is the UNEP standardized toolkit for identification and quantification of dioxin and furan release (2013 version), the BAT/BEP Guidance for ANNEX C substances under the Stockholm Convention, and dioxin emission inventories for various countries.

Dioxins may be released from most thermal processes, but it is considered that the processes relevant for potential initiatives are the Stockholm Convention Annex C, part II source categories or processes demonstrated to be among the main sources in national inventories of PCDD/F emission. In the following table the considerations for each category is shortly summarised. Hot Spots with potential PCDD/F issues are further described below the table.

		2013 status	Remark concerning PCDD/F
M1(1)	Pechenganickel MMC of Kola	AE – in progress (TAE) VD – in progress (TAD)	Primary nickel production is not considered a significant dioxin source
SM2(2)	Monchegorsk industrial site of Kola GMK, Monchegorsk	AE – solved (MAE)	Primary copper production is not considered a significant dioxin source

M3(3)	Apatit JSC, Kirovsk	AE – in progress (TAE) VD – in progress (TAD)	Phosphate production is not considered a significant dioxin source
M4(4)	Apatity HPP of TGK-1, Apatity	AE – solved (MAE)	Coal power plants are not considered significant dioxin sources
M5(5)	Kovdorskiy GOK of Eurochem, Kovdor	VD – in progress (TAD)	Apatite mining is not considered a significant dioxin source
M6(6)	Water quality in the Kola River and Bolshoye Lake	VD – in progress DV – partly solved	Drinking water quality - no dioxin issues
M7(7)	Drinking water supply in Zelenoborsky-1	DV – partly solved	Drinking water quality - no dioxin issues
M8(8)	Mercury-containing waste management	WM - solved	Mercury recycling - no processes where dioxins may be formed
M9(9)	Sunken and abandoned ships in the Kola Bay	WM – partly solved	Dumped ships - no information on any dioxins issues, but probably not relevant
M10(10)	Oil-containing waste management	WM – in progress	Oil containing waste - Based on the description, the Hot Spot seems mainly to manage oil-containing wastewater. Most probably, the operations do not include treatment of wastes contaminated with transformer oils which may contain PCB but it cannot be ruled out. The final treatment of the oil waste is indicated as "biological treatment" and consequently with no dioxins issues.
K1(11)	Kondopoga JSC, Kondopoga	AE – solved (MAE)	Paper production - contaminated sites - - no indication of dioxins. Potential dioxin issue - see below.
K2(12)	NAZ-SUAL branch, Nadvoitsy	AE – partly solved (MAE)	Primary aluminium production is not considered a significant dioxin source
K3(13)	Drinking water supply in towns and settlements of the Republic of Karelia	DV – in progress	Drinking water quality - no dioxin issues
K4(14)	Drinking water quality in water supply system of Petrozavodsk	DV – solved	Drinking water quality - no dioxin issues
K5(15)	Sewage treatment in Petrozavodsk	VD – in progress	Municipal waste water - no dioxin issues
K6(16)	Sewage treatment in small towns and settlements in the Republic of Karelia	VD – in progress	Municipal waste water - no dioxin issues
K7(17)	HPP burning fuel oil and coal in the Republic of Karelia	AE – in progress EE – in progress	Boilers are not considered significant dioxin sources
K8(18)	Waste management in the Republic of Karelia	WM – in progress	Potential dioxin issue See description below
K9(19)	Waste dumping ground,	WM – in progress	Casting process waste - no dioxin issues

	Gorelaya Zemlya in north Petrozavodsk	PD – partly solved	
K10(10)	Stocks of obsolete pesticides	WM – solved PD – solved	Solved - no more stocks
A1(21)	Solombala PPM of Solombalales, Arkhangelsk	AE – partly solved (TAE) VD – urgent	Paper mill - no indication of dioxins Potential dioxin issue - see below.
A2(22)	Arkhangelsk HPP of TGC-2, Arkhangelsk	AE – solved (MAE)	Gas-fuelled power plants are not considered significant dioxin source
A3(23)	Severodvinsk HPPs of TGC-2, Severodvinsk	AE – solved (MAE)	Coal-fuelled power plants are not considered significant dioxin source
A4(24)	Arkhangelsk PPM, Novodvinsk	AE – solved VD – solved	Gas-fuelled power plants are not considered significant dioxin source
A5(25)	Koryazhma branch of Ilim Group, Koryazhma	AE – solved VD – solved	Pulp and paper - no indication of dioxins Potential dioxin issue - see below.
A6(26)	Waste management in the Arkhangelsk region	WM – in progress	Waste management Potential dioxin issue - see below.
A7(27)	Areas of past environmental damage in the Arkhangelsk region	PD – in progress	Petroleum fuel and spent motor oils - no dioxin issues (motor oils do not contain PCB)
A8(28)	Spent motor oil management in the Arkhangelsk region	WM – partly solved	Spent motor oil - no dioxin issues (motor oils do not contain PCB)
A9(29)	Dioxin pollution in the Arkhangelsk region	WM – solved	Dioxin issues See comments below
A10(30)	Stocks of obsolete pesticides in the Arkhangelsk region	WM – solved PD – solved	Solved - no more stocks
N1(31)	Kumzhinskoye gas and condensate field	PD – in progress	Gas and condensate field - no dioxin issues
N2(32)	Drinking water supply in the Nenets Autonomous District	DV – in progress	Drinking water quality - no dioxin issues
N3(33)	Wastewater treatment in Naryan-Mar, Nenets Autonomous District	VD – in progress	Waste water treatment - no dioxin issues
N4(34)	Mercury-containing waste management	WM – solved	Collection and treatment of mercury lamps - no dioxin issues
Ko1(35)	Vorkutaugol JSC coal mines, Vorkuta	AE – in progress EE – in progress	Greenhouse gas emission from coal mining - no dioxin issues
Ko2(36)	Cement Northern Company and Vorkuta HPP,	AE – partly solved, in progress	Vorkuta cement plant - dioxin issues addressed by the current project

Vorkuta			
Ko3(37)	Mondi Syktyvkar JSC, Syktyvkar	AE – solved (MAE) VD – in progress	Coal power plants are not considered significant dioxin sources
Ko4(38)	Sewage treatment in small settlements in the Republic of Komi	VD – in progress	Municipal waste water treatment - no dioxin issues
Ko5(39)	Drinking water supply in the Republic of Komi	DV – in progress	Drinking water quality - no dioxin issues
Ko6(40)	Waste management in the Republic of Komi	WM – in progress	Waste management Potential dioxin issue - see below.
Ko7(41)	Wood processing industry waste management	WM – in progress EE – in progress	Use of wood waste for heat and power - no dioxin issues
Ko8(42)	Coal mining industry waste management	WM – in progress EE – to be launched	Coal mining waste - no dioxin issues

Industrial air emissions (AE), wastewater discharges (VD), waste management (WM), drinking water supply (DV) and past environmental damage (PD). Some "hot spots" were also relevant to energy-efficiency issues (EE)-

Dioxin pollution in the Arkhangelsk region: A9(29)

This Hot Spot is the only specifically addressing dioxins issues in the region. According to the AMAP/NEFCO list from 2003 ³, the main enterprises in Archangelsk that can form dioxin and dioxin-like by-products in the basins of Northern Dvina and Onega rivers were:

- 1 Timber processing using pentachlorophenol (PCP): Solombala TPCP, TPCP-1, TPCP-2, TPCP-3; Tsiglomen TPCP; Kegostrov TPCP; Kuznechevsky TPCP TP-2, TP-3, TP-12, TP-14
- 2 Pulp and paper: Arkhangelsk PPCM (Novodvinsk)

According to the 2003 review, surveys made in Solombala TPCP, Onega TPCP, Shalakusha TP and TP-2 have shown that soil pollution at these enterprises, which used sodium pentachlorophenol (Na-PCP) reached 1.1 mg/kg of this toxicant. Dioxin levels were also high. For example, dioxin levels at the territories of Onega TP and TP-2 at the surface layer (0-10 cm) was 0.2-830 µg/kg in TE, and 69.4 µg/kg at the depth of 60-80 cm. According to tentative estimates, total amount of dioxin and furans in soil in 1999 was 1.3 kg from the basins of Northern Dvina and Onega rivers, including 0.8 kg in Arkhangelsk.

According to the 2013 review, elemental chlorine free technology for bleaching has been introduced at Arkhangelsk PPM and land contaminated with dioxin from wood impregnation with Na-PCP at Onezhsky SWP has been rehabilitated and fully

³ Updating of Environmental "Hot Spots" List in the Russian Part of the Barents Region: Proposal for Environmentally Sound Investment Projects

paved with asphalt. According to the review, in 2012, the Agency on Nature Protection and Ecology of the Arkhangelsk region proposed to exclude the A9 "hot spot" from the Barents Environmental "Hot Spot" List.

The Onezhsky SWP is not mentioned in the 2003 report. The 2003 report mention 4 sites in Archangelsk (listed above) and 11 sites in the entire region that may be contaminated with PCP and dioxins from the former use of Na-PCP for impregnation. No data are provided in the 2013 review of any of these sites and thus no documentation for exclusion of the Hot Spot is provided. It is indicated that information on other sources of dioxin pollution in the region is not available. More information is needed for a further assessment of potential dioxin contamination of other spots for timber impregnation.

With the introduction of elemental chlorine free technology at Arkhangelsk PPCM, the formation of dioxins is highly reduced. One dioxin issue may be landfilled waste water treatment sludge from former activities. More information is needed for the assessment of landfilled sludge as a possible dioxin source.

Management of municipal solid waste: K8(18), A6(26), Ko6(40)

Uncontrolled burning of waste (e.g. "backyard burning") and landfill fires are among the major sources of dioxins in many countries. Projects aiming at reducing emission of dioxins from municipal solid waste would typically contain:

- 3 Development of legal framework for restriction of uncontrolled burning of waste and for proper management of landfills and waste dumps in order to reduce the risk of landfill fires.
- 4 Development of efficient waste collection systems.
- 5 Development of guidelines and procedures for proper management of landfills (e.g. soil cover)

The Hot Spot activities include, according to the description in the 2013 review, development of waste collection systems and establishment of landfills.

Paper production: K1(11), A1(21), A5(25)

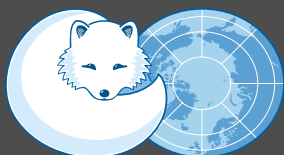
Three production sites for pulp and/or paper (Kondopoga, Solombala (also addressed by A9(29)), Koryazhma/Kotlas) are included in the hot-spot list. For none of the sites the review address the dioxin issues. The 2003 review includes Solombala (also addressed by A9(29)) and Koryazhma/Kotlas in the list of major sources of dioxins due to the use of elemental chlorine for bleaching. The 2013 review mention that alternative bleaching have been introduced at the Solombala, but do not include any information on bleaching for the other plants.

For the Koryazhma/Kotlas plant A5(25), the review list different measures taken but, substitution of elemental chlorine bleaching is not among the measures. If the plant still use elemental chlorine bleaching this would be a major issue. For the Kondopoga plant (K1(11)), no information on bleaching method is provided in any of the reviews.

As mentioned above for A9(29), one remaining dioxin issue (if alternative bleaching has been introduced) may be landfilled waste water treatment sludge from former activities. More information is needed for the assessment of landfilled sludge as a possible dioxin source.



ARCTIC CONTAMINANTS
ACTION PROGRAM



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