PAPER FOR COMEAP
USE OF SUBSTITUTE FUELS IN CEMENT KILNS

Introduction

1) In 1997 and 1998 COMEAP agreed statements on the possible health effects of air pollutants in the Clitheroe area relating to the Castle Cement works and the use of Substitute Liquid Fuel (SLF). At the time the Committee examined a summary of the Environment Agency (EA) monitoring data, a report on dust monitoring in the vicinity of Clitheroe hospital, a paper on information collected by EA on complaints and odours, together with information on action taken by the EA, and health data collected by the East Lancashire Health Authority.

2) The Committee concluded that the data available to it did not indicate that air quality in the area was worse when SLF was burnt compared to coal, nor did the data point to the need for a survey of health of the local population to be carried out.

3) The Castle Cement works at Clitheroe was the first in the UK to burn SLF. The use of substitute fuels in cement kilns is now widespread and is subject to the Integrated Pollution Prevention and Control (IPPC) regime. The NHS Primary Care Trusts (PCTs/Local Health Boards(LHBs)) are ‘Statutory Consultees’ for this regime; statutory consultees are considered to have special knowledge or expertise. The Health Protection Agency (HPA) supports the PCTs/LHBs in this process.

4) The use of substitute fuels in cement kilns has given rise to considerable public concern. The HPA has produced an interim position statement on the public health consequences of these processes (this is attached in Annex 1). It is seeking the advice of COMEAP on this issue before finalising its position.

Advice from COMEAP

5) The HPA is seeking the advice of COMEAP on this issue, and specifically whether its conclusions in 1997 and 1998, as summarised in para 2 above, can be extended to other sites and the use of other substitute fuels.

6) In order to facilitate this process it was felt that it would be best to provide detailed information, including monitoring data, relating to representative sites (as agreed with the EA) in the first instance. The Committee's discussion of this could then be used to inform decisions as to the information that would be necessary on the other sites in order to allow more generic conclusions to be drawn.

Background information on Cement kilns

7) Portland cement is defined as a binder formed from ground clinker made from a mixture of lime (CaO) and silica (SiO_2) with a small proportion of alumina (Al_2O_3) and iron oxide (Fe_2O_3). The components are blended, dried and calcined (production of CaO from the $CaCO_3$ of the limestone or chalk) at about 800-900°C. This is followed by sintering at 1450°C, where the CaO reacts with the other components in a liquid state to form calcium silicates, aluminates and aluminoferrite, the main components of cement. Gas temperatures of about 2000°C are required to heat the raw materials to c.1450^{o}C and are generated by the combustion of high calorific value fuel. The liquid is cooled to 1100 °C where crystals of the reaction products form, followed by cooling to 250°C in a clinker cooler. The clinker is then ground and gypsum added to control the setting time of the final cement product (Environment Agency 1996). The process is very energy intensive and energy costs typically comprise 65-75 % of total processing costs.

8) The process can be wet, dry, semi-wet or semi-dry. Annual production of cement is about 14 million tonnes in the UK (produced mainly in 22 kilns, of which 13 (39%) are wet processes (International Cement Review (ICR) 2003).

9) The wet process involves feeding a slurry of component materials to the cement kiln which is then dried; a highly energy intensive process. Typical slurry moisture content is 30-40% water. The slurry is pumped from storage tanks to the back end of the kiln. The slurry gradually moves towards the flame at the burning end of the kiln where drying, calcining and sintering take place. Larger fans are required than in the other systems to remove the large amount of steam produced and consequently higher volumes of combustion products are produced. While there is a programme of capital investment and replacement of old wet plants with modern dry plants (House of Lords 1999), it is still common in the UK where chalk is produced in a slurry form.

10) In the dry system the feed materials are pre-heated in a series of cyclones. Raw materials are dried, ground and pre-heated in a series of cyclones. After the pre-heater, the hot material enters the rotary kiln having been calcined by up to 20%. Heating is provided from combustion of fuel using hot combustion gases derived from the kiln exit and also from the grate which cools the clinker after it exits the rotary kiln.

11) In the semi-wet process the slurry of feed material is mechanically pressed to remove water and produce a cake of feed material which is then dried and partly calcined in a pre-heater.

12) The semi-dry process mixes the dry feed material with water to form nodules which deliver the feed material to the rotary kiln. The feed material moves counter-current to a hot air stream.

13) There are four major companies in the UK producing cement – Lafarge, BLI, Castle Cement and Rugby Cement. The technology used by the companies includes wet, dry, semi-dry and semi-wet processes. Table 1 lists those sites which have been granted permission to burn fuels continuously following a successful trial and table 2 lists the status of current or proposed trials- if these trials go ahead and are successful, the operator will apply for permission to burn the fuels continuously. The cement process is very energy intensive and the industry has moved to reduce fuel costs including sourcing alternative

non-fossil derived fuels. The main alternative fuels used by the cement industry are Substitute Liquid Fuel or Secondary Liquid Fuel (SLF) and used tyres. SLF is produced by blending organic wastes. The wastes are derived as solvent wastes produced by the chemical industry, but also include some aqueous wastes and wastes containing high concentrations of halogen or metal contents. For any type of source of waste, the exact chemical constituents and composition and composition can vary widely. The main constituents of SLF include solvents, working fluids (oils, lubricants, etc.), contaminated fuels, organic sludge (e.g. food industry wastes) and other organic chemical products. Scrap tyres are also an alternative fuel used in cement manufacture since the rubber has a high calorific value. The type of material which can be used as substitute fuel is subject to the requirements of the Environment Agency's Substitute Fuels Protocol. See table 3 for fuels currently burned.

Table 1 Sites currently authorised to burn substitute fuels

Company	Site Name	Max. Substitution Rate	Comments
Castle Cement	Clitheroe	kilns 5,6 &7 @ 40% SLF	
	Ketton	kiln 7: @40%SLF, 25% whole tyres and 40% Profuel. kiln 8: @25%SLF and 50% Profuel	
Lafarge Cement	Cauldon	1 kiln @44% tyre chips (6.5t/hr back end fuel)	Back end substitution rate (73.11%.) limited by need to maintain flame temperature with coal feed.
	Cookstown	1 kiln @ 12% whole tyres	Regulated by EHS -NI Feed equipment to be installed
	Dunbar	1 kiln @40% SLF and 24% tyre chips (4t/hr)	Regulated by SEPA
	Hope	kilns 1 & 2, @23% tyre chips	
	Westbury	kilns 1 & 2 @ 24% whole tyres	
Rugby Cement	Barrington	1 kiln @ 40% SLF	
	South Ferriby	kiln 2@ 40%SLF kiln 3@ 40% SLF	
Lafarge- Lime	Thrislington	T3 kiln @ 40% SLF	T2 kiln mothballed
	Whitwell	2 kilns @ 25%SLF or 1 kiln @ 40%	

Table 2 Status of Current or Proposed Trials

Company	Site Name	Substitution Rate	Comments
Castle Cement	Clitheroe	kiln 7 @ 25% tyre chips	Complete. Trial report resubmitted March'04.
		kiln 7 @ 50% MBM	Application received. Schedule 7 notice issued.
		kiln 7 increase tyre chip substitution rate up to 50%	Application anticipated early 2005.
	Ketton	MBM	Application anticipated May/June'04.
	Padeswood	SLF/Profuel/Tyres fuel mix planned for new kiln.	Commissioning programme scheduled Nov 2004. tbc
Lafarge Cement	Cauldon	kiln 1 – main burner @17 % sewage sludge (4.5t/hr)	Trial complete. Trial report submitted. Permit variation anticipated March'04
		kiln 1 pre-calciner @ up to 40% sewage sludge	Trial anticipated Sept/Oct 2004.
	Cookstown	1 kiln @ 40% SLF	Commissioning in progress. (Regulated by NI-EHS)
	Westbury	kiln 1@ 40% SLF	Application received end of June'03. Trial planned mid 2004.
Lafarge- Lime	Thrislington	T1 kiln @ 40% SLF	Trial complete. Trial report submitted. Further application required for permanent use.
Rugby Cement	Barrington	kiln 4 @ 30% packaging waste	Application for packaging waste received Jan'03. Schedule 4 issued. Operator has yet to respond. Determination period to be extended further. Trial planned Aug 2004.
	Rugby	kiln 7@ 40% tyre chips (10t/hr)	Trial in progress.
	South Ferriby	kilns 2 & 3 @ 15% tyres (whole and chipped)	Trials planned 2004.

Table 3 Summary of cement and lime kilns (England & Wales) burning substitute fuels and planned trials

January 2005

Site	**Operator**	**Kiln Type** **PC-Precalciner** **PH-Preheater**	**Capacity t/day**	**Fuel**
Aberthaw	Lafarge	Dry	1700	C/PC/MBM[D]
Cauldon	Lafarge	Dry/PC	2800	C/T/SS
Hope 1	Lafarge	Dry/PH	1900	C/PC/T
Hope 2	Lafarge	Dry/PH	1900	C/PC/ T
Holborough[A]	Lafarge	Dry/PH/PC	4300	C/PC/T
Westbury 1	Lafarge	Wet	950	C/PC/T/SLF [B]
Westbury 2	Lafarge	Wet	950	C/PC/T/SLF [B]
Ketton 7	Castle Cement	Dry/PH	1060	C/PC/CEM/PRO/T
Ketton 8	Castle Cement	Dry/PC	3100	C/PC/CEM/PRO
Padeswood 4 [C]	Castle Cement	Dry/PH/PC	2350	C/PC/CEM/T/PRO
Ribblesdale (Clitheroe) 5	Castle Cement	Wet	950	C/PC/CEM
Ribblesdale 6	Castle Cement	Wet	1050	C/PC/CEM
Ribblesdale 7	Castle Cement	Dry/PH/PC	2500	C/PC/T/CEM/MBM[D]
Barrington 4	Rugby Cement	Wet	770	C/PC/SLF
Rugby	Rugby Cement	Dry/PH/PC	4000	C/PC/T[E]
South Ferriby 2	Rugby Cement	Semi dry	1100	C/PC/SLF
South Ferriby 3	Rugby Cement	Semi dry	1100	C/PC/SLF
Thrislington T1 (Lime)	Lafarge	Rotary/dry/PH	624	C/PC/SLF
Thrislington T3 (Lime)	Lafarge	Rotary/dry/PH	1920	C/PC/SLF

Whitwell 1 (Lime)	Lafarge	Rotary/dry	500	C/PC/SLF
Whitwell 2 (Lime)	Lafarge	Rotary/dry	500	C/PC/SLF

[A] Plans to build the new cement kiln at Holborough have been postponed.
[B] Permission to burn SLF is subject to successful completion of trial (kiln 1 or 2) and further application.
[C] New kiln under construction, when commissioned in 2005, it will replace three existing kilns at Padeswood and two wet kilns at Ribblesdale.
[D] Permission to burn MBM is subject to successful completion of trial.
[E] Permission to burn tyres is subject to successful completion of trial.

Fuel key:
C – Coal, PC – Petroleum coke
CEM – Cemfuel, MBM – Meat and bone meal, PRO – Profuel
SLF - Substitute liquid fuel, SS - Sewage sludge, T – Tyres

Published data on emissions and health impact

15) The main releases to air from cement production arise from the kiln stage via the kiln exhaust gases, clinker cooler exhaust and any bypass gases. A number of studies have suggested that the use of wastes in cement kilns is no more polluting to the environment than the use of conventional fuels. Environment Agency Sector Guidance note IPPC S3.01 suggests that the burning of tyres and tyre chips significantly reduces NOx levels in cement manufacture by between 20%-40% (Environment Agency 2001). The use of tyres has been proposed to reduce NOx levels by the formation of reducing zones when the tyres are being burned. It has also been proposed that the use of SLF at a fuel input level of 40% reduced NOx emission levels by 50%, (House of Lords 1999). It was also reported that the wide variability in NOx emissions from wet kilns was reduced by the use of SLF (House of Lords 1999). Lowes (2001) has shown a 20% reduction for NOx emissions from a cement plant for a 25% supplement of tyre chips.

16) The data also showed the variability of NOx from cement kilns with some baseline data producing lower emissions of NOx than with tyres. The reduction in NOx emissions when tyres were used was also confirmed from data from the USA for the Atlanta EPA compliance tests (Lowes 2001).

17) The highly alkaline conditions decompose chlorinated organic wastes and acid gases and the process retains a large proportion of waste material within the clinker itself. Because of the counter current flow of feed material and combustion air, many of the pollutants which potentially could be released to air are trapped in the clinker. While some SO_2 releases are trapped by incoming lime, there are still significant emissions of SO_2 from cement kilns. However, emission data for SO_2 have also shown no significant difference when SLF was combusted compared to coal. SO_2 emission data from three UK cement kilns burning coal and SLF have been reported (House of Commons 1997). These showed no significant difference when SLF was combusted compared to coal. AEA Technology considered that there were no significant difference in SO_2 emissions whether coal or coal plus SLF was combusted in cement kilns (House of Commons 1997).

18) The very high temperatures and long residence times achieved in the kilns produce a highly efficient environment for the destruction of organic compounds. For example, destruction and removal efficiencies for chemicals such as methylene chloride, carbon tetrachloride, trichlorobenzene, trichloroethane and polychlorinated biphenyls (PCBs) have typically been measured at 99.995% or better (Eduljee 1999). Sarofim et al identified that laboratory data on the oxidation of organic compounds have shown that ideal cement kiln conditions far exceed the requirement for >99.99% Destruction and Removal Efficiency (DRE) (Sarofim 1994). Given that data on pyrolysis of organic compounds have shown that higher temperatures may be required for this level of DRE, they reviewed data from 17 kilns and demonstrated a destruction efficiency of >99.9999% for organic compounds. This is supported by Sidhu et al who concluded that effectively managed cement kilns provide sufficient reaction time, oxygen concentration and temperatures to destroy or remove all organics present in the fuel feed at greater than 99.99% efficiency (Sidhu 2001).

19) Sarofim el al found that neither the type of cement kiln nor the form of the waste derived fuel had any major influence on PCDD/PCDF emissions. Similarly, Schreiber et al reported on cement kiln dioxin emission tests during one week in 1994 under differing

operational conditions and using coal, liquid waste fuel and solid waste fuel and found no significant differences in emissions (Schreiber 1995).

20) Eduljee and Dyke screened a range of UK industrial processes for potential to release PCDD/Fs (Eduljee and Dyke 1996). Key processes were assessed to estimate the annual quantities of PCDD/Fs released to atmosphere. Municipal solid waste incinerators were responsible for 70% of total industrial emissions with local combustion, sintering, metal processes and clinical waste incineration contributing a further 25%. Cement kilns were estimated to be responsible for between 0.03% and 1% of total estimated emissions. The authors also found no difference between measured emissions when the kilns were fired with coal only, or with coal/supplementary fuel mixture.

21) Kuhlmann et al examined data on PCDD/F emissions from 16 cement kilns in Germany (Kuhlmann 1996). The type of fuel made no significant difference to emissions and the authors concluded that the formation of PCDD/F is not influenced by the co-firing of 'alternative' fuels.

22) Eduljee reviewed dioxin formation and control in cement kilns and examined emission data (Eduljee 1999). Comprehensive studies have generally concluded that there were no significant differences in emissions when using conventional or substitute fuels.

23) Research from Catalonia, Spain has indicated that cement kilns are insignificant sources of metal or PCDD/PCDF contamination. Schuhmacher et al examined levels of PCDD/PCDF and various metals in soil and herbage samples around a cement plant in Spain (Schuhmacher 2002). Samples were taken following a plume dispersion model and an assessment of population distribution. Results showed no significant differences in levels within 3.5 km compared with samples taken beyond 3.5 km of the kiln and no differences in comparison to rural areas with no known industrial sources.

24) Emissions of refractory metal compounds are generally below 0.1% of input and as low as 0.001% for the least volatile metals (Sarofim 1994)**.** Guo and Eckert examined data

from a cement kiln burning hazardous waste fuel and found no differences in the distribution of heavy metals in the three outputs (stack emissions, cement kiln dust and clinker) (Guo and Eckert 1996). Heavy metals released in the kiln system are absorbed by the clinker due to the high alkaline content of the clinker and the scrubbing action within kilns. Refractory metals such as Ba, Be, Cr and As tend to be incorporated into the clinker at approximately 99.9%. About 99.5% of the semi-volatile metals such as, Cd, Pb, Zn are also trapped in the clinker. The more volatile metals such as Hg and Tl are largely released into the kiln exhaust gas and are controlled by the gas clean-up system. The use of electrostatic precipitators to trap particulate enables the collected dust to be returned to the feed for subsequent processing. However, there may be releases to land of cement kiln dust if the dust is not suitable from a quality control point of view for recycling.

25) The main emission to land is cement kiln dust (CKD). CKD is a powder composed principally of micron-sized particulates collected from electrostatic precipitators during the high temperature production of cement clinker. The chemical composition of CKD depends both on the raw materials used to produce the clinker and the type and source of fuel/waste used to heat the material in the kiln.

26) Life cycle assessment studies (Environment Agency 1999) indicate that SLF combustion in cement kilns is preferable compared to hazardous waste incineration.

27) The use of cement kilns to burn these wastes also has benefits to the UK in meeting its obligations under the Kyoto accord and European legislation (the EU Landfill Directive for example prohibited landfill disposal of whole scrap tyres in 2003 and shredded tyres will be prohibited by 2006).

28) There is very little evidence published in the peer-reviewed literature on the health impact of burning substitute fuels in cement kilns. However, a great deal is known about the process characteristics from the extensive use of these fuels in Europe and trials conducted in the UK and elsewhere. The process environment means that substitute fuels

are no more polluting to the environment than conventional fuels and for some key pollutants actually less so.

29) Sarofim considered that the use of waste as a substitute fuel in cement kilns is ‘fundamentally sound in theory, and in a number of cases, has been demonstrated sound in practice’ (Sarofim 1994). Holcomb and Pedelty reviewed the evidence of carcinogenicity and evaluated the exposure to dioxins from combustion sources and specifically, cement kilns (Holcomb and Pedelty 1995). The paper identified a number of risk assessments on cement kilns. While these studies vary in many respects, the overall risk estimate is in the 10^{-6} to 10^{-7} range (i.e. one case of cancer in a maximally exposed person – assumed to receive maximum exposure 24 hours a day, 365 day a year – in a population between1,000,000 to 10,000,000). This is insignificant when compared to background environmental levels. The authors conclude that ‘… it is evident that risks due to exposure to cement kiln emissions are insignificant when compared to that from background exposures’ (it should be noted that the use of such mathematical estimation of low dose cancer risks from animal bioassays is not recommended in the U.K. and such an approach is considerd particularly inappropriate for 'dioxins' as they are non-genotoxic and have a threshold to their carcinogenic effects).

30) As noted earlier COMEAP have previously considered possible health effects of air pollutants in the Clitheroe area (site of the Castle cement works). The committee examined a summary of the monitoring data published by the Environment Agency and further data collected in 1997 on local concentrations of volatile organic compounds. The Committee recognised that the general concentrations of SO_2 and particulates in the area did not appear to be exceptional, although data were not available to make comparisons with other parts of the UK. Nor was there any persuasive evidence that general levels of air pollution in the area were a cause for concern. Nevertheless, complaints of deterioration in air quality appeared to coincide with short-term peaks of SO_2 and plume grounding events arising from Castle Cement. Complaints occurred at a similar level when either SLF (in this case, Cemfuel) or coal were burnt. The burning of SLF did not appear to prevent such incidents from occurring. The Committee considered some additional data on volatile

organic compounds made available to it. From the limited data made available, it did not appear that the burning of SLF had any effect on the levels of such compounds found in the area.

31) In an update to the above statement, the Committee examined data collected by the EA on complaints and odours in the Clitheroe area. It was satisfied that there did not appear to be a link between complaints or odour threshold exceedances and the burning of SLF during the monitoring period and that the concentrations of substances detected in ambient air samples did not indicate any concerns for health. The committee concluded the data available to it did not indicate that air quality in the area was worse when SLF was burned when compared with coal nor did the data point to the need for a survey of the health of the local population to be carried out.

Sites chosen for initial consideration by COMEAP

32) The EA has provided details of emission and available ambient monitoring data from two sites; Ketton (dry process burning tyres and SLF) and Westbury (wet process burning tyres). An air quality assessment for the latter is given in annexes 2 and 3 and details of the former will be forwarded prior to the meeting (as soon as made available by the EA).

Advice from COMEAP

35) Is the available information sufficient to allow the Committee to draw similar conclusions regarding the Ketton and Westbury sites to those reached by the Committee when considering the burning of SLF at the cement kiln in Clitheroe (given in para 2 above)?

36) If not is there further information needed by the Committee to allow a conclusion to be drawn?

37) What information is needed from the other cement kilns burning substitute fuels to allow more generic conclusions to be drawn?

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