Cement Kilns – groundWork Report

Analysis and write up of burning alternative fuels in cement kilns

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This report was prepared for groundWork by Jane Harley as part of a joint project with NiZA (Nederlands Institute Zuid Afrika). An attempt was made to refer only to those studies which relate directly to cement kilns, rather than to incineration in general, and to distil the information in as succinct a manner as possible.

Cement Kilns (Report as at November 2006)

Concrete, a vital element of which is cement, is the second most consumed substance in the world. Only water is used in greater quatities [W01]. Apparently, almost one ton of concrete is used for each person in the world each year [W02]. The amount of concrete used in construction around the world is more than double that of the total of all other building materials, including wood, steel, plastic and aluminium [W03].

Currently, production of cement is in the region of 1.5 billion tons per annum [W04], with a projected 2 billion tonnes (2000 megatonnes) production by 2010 [W05]. This should be of grave concern to all, as the manufacturing of cement is intrinsically unsustainable, and has serious environmental impacts.

At the moment sixteen cement companies, which together represent more than 50 percent of the cement manufacturing capacity outside of China, have formed The Cement Sustainability Initiative (CSI), a member sponsored program of the World Business Council for Sustainable Development (WBCDSD) [W06]. Holcim and Lafarge, both active in South Africa, are core members of the CSI. The South African Cement Producers Association (SACPA) is listed as a communication member [W07], although it would appear that this organisation was delisted as an employer in 2004 [W08] and an internet search has raised no recent references. The organisation which appears currently to represent South African cement interests is the Cement and Concrete Institute, whose "prime objective [is] to increase the market share of concrete for its members, in the building materials sector" [W09]. Its producer members are Holcim, Lafarge, Natal Portland Cement (NPC) and Pretoria Portland Cement (PPC) [W10].

The Cement Sustainability Initiative has put out a great many documents, all of which avoid the central truth – that cement can never be sustainably produced. While the industry is fond of saying that cement is the glue which holds society together, it generally neglects to point out that the industry is also responsible for a disproportionate volume of CO_2 and other green house gas emissions, for massive fossil fuel consumption, for the creation of huge volumes of particulate matter, for the emission of large amounts of mercury and for environmental impacts through the mining of quarries and so on. While, in fairness, the industry is making some genuine environmental adjustments, we should not lose sight of the fact that a more honest approach to sustainability would be to make real investments in research into sustainable alternatives to cement, and to building methods which do not require concrete or cement, and which are less harmful to the environment

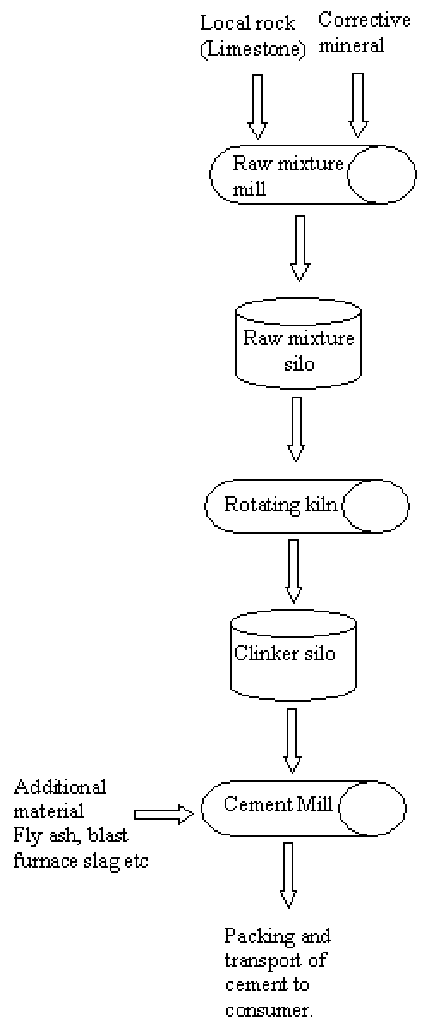
An area where the cement industry is particularly focussed at present is the use of what they term "alternative fuels", which translates to the use of waste as a fuel. We must also not allow the industry's current attempts to paint the use of "alternative" fuels and waste materials green to go unchallenged – in the end, the use of waste in the cement industry is no more sustainable than current practices, and potentially brings with it a number of new problems.

This report seeks to outline the cement industry with reference to the kilns used to produce clinker, and to provide comment on the possible exacerbating effects of burning waste in these kilns. It will be seen that this aspect of the cement making industry impacts severely on the environment. The other aspects – quarrying, milling, bagging and transporting – have there own problems, but are not addressed in any detail here.

Cement Manufacture[1]

Cement is essentially a binding agent which is used in concrete, mortar and plaster. It consists of four elements, calcium, silica, alumina and iron, which are found in limestone, clay and sand. To manufacture cement, four main processes are followed.

Firstly, raw materials are quarried and transported to a cement facility. These materials would include lime, shells or chalk, silica or fly ash from coal combustion, alumina from clay or shale or fly ash from coal combustion and iron oxide from iron ore or from iron containing by-products.



Next, these raw materials are milled into a fine powder and are mixed thoroughly. This mixing may be done using water or compressed air.

The next step is to heat the elements at very high temperatures (between 1400° and 1500°C), in a cement kiln. What is placed in the kiln can be either wet or dry. In the dry process, raw materials are in a fine dust form, and in the wet process in a slurry form. Generally, wet kilns are older and dry kilns are more modern and fuel efficient.

The kiln is an enormous sloped cylinder which slowly rotates. Temperatures increase over the length of the cylinder to very high temperatures – around about 1500°C - and the fuel is fed directly into the kiln, meaning that the fuel residues are incorporated into the final product. The temperature has to remain regulated, because if it is too low the product will not become sintered (i.e. the small particles of the raw materials will not adhere to one another correctly) and if it is too high the particles will melt and fuse into large glass-like lumps.

There are four thermal zones through which the raw materials travel in the kiln. The first is known as the Calcining zone, and it is here that limestone undergoes a chemical conversion to become lime. This occurs at about 900°C and the liberation of a CO_2 molecule from the limestone (calcium carbonate - $CaCO_3$) to form lime (calcium oxide - CaO) is known as calcination. The second zone is known as the Upper-transition zone, and here the temperature of the materials is increased to about 1200°C. In the third zone, the Sintering or Burning zone, the temperature is increased to about 1450°C, and it is at this point that the clinker, grey, glass-hard pellets, is formed. The last few meters of the kiln form the fourth zone, the Cooling or Lower-transition zone, and here the clinker is cooled to around 1250°C. The clinker then drops into a cooler and is taken for storage, where it can be kept for a number of years before being used.

In the final step of cement manufacture, about two percent gypsum (calcium sulphate), along with various other materials, is added to the clinker to improve the cement's setting and handling

[1] Information for this section is drawn from http://en.wikipedia.org/wiki/Portland_cement (16 August 2006), Commission for Environmental Cooperation, p 36 and PPC EIA BID, p. 6. The diagram comes from the Wikipedia.

qualities, and everything is then finely ground into a powder which will react to the addition of water.

Environmental Problems with Cement Manufacture

Energy and Fuel

Because the process of turning limestone into clinker requires high temperatures, the cement industry is one of the most energy intensive industries, consuming about 10 times more energy than the average required by industry in general. Modern dry-process kilns, however, require far less energy than the older, wet-process kilns [W11], and the use of pre-burners and the re-use of air from the clinker coolers can further reduce the amount of energy required. However, in the US in 2003, 25 kilns at 14 plants used hazardous waste as a fuel and most of these used the older, wet process [Commission for Environmental Cooperation, p. 36].

Historically, fuels used to fire cement kilns include pulverised coal, petroleum coke, which is a by-product of oil refining, and natural gas. More recently, "alternative fuels" such as used solvents, spent tyres, waste oil, paint residue, biomass such as wood chips, treated wood and paper, and sewerage sludge have also been used [ibid, p. 36].

The burning of hazardous and non-hazardous waste is also euphemistically known as co-processing, secondary materials co-processing or energy recycling. Waste fuels are very attractive to the industry as energy makes up the major cost in the manufacture of cement and such fuels are generally cheaper than the traditional fuels. Tyres and used industrial solvents are particularly attractive as they have calorific (energy) values similar to that of coal. Sometimes, waste can have an added benefit in that the kiln operator may, in fact, be paid for incinerating the waste. In certain countries, because the use of waste fuels reduces the use of oil and gas, carbon dioxide emission credits can be claimed [ibid, p. 36].

WASTE TYRES AS A POTENTIAL CEMENT KILN FUEL IN SOUTH AFRICA

In South Africa, a draft Memorandum of Agreement (MOA) has been discussed between the Department of Environmental Affairs and Tourism (DEAT) and the waste tyre industry. Although it is not explicitly stated, the language of the memorandum certainly appears to open the door to cement kilns burning spent tyres in their kilns, and possibly even to the import of tyres for this purpose [DEAT 2006].

Within the MOA, "waste tyre users" are defined as "any tyre derived fuel user or waste tyre recycler", which are respectively defined as "a person or institution engaged in energy recovery from waste tyres" and "any person or institution, using any process by which waste tyres are converted or transformed into new products, or raw materials for any purposes, excluding energy recovery and/or any other process by which a used tyre is retreaded or repaired for return to its original intended use".

Waste tyre users will contract to the South African Tyre Recycling Process Company (SATRP), and will tender for the waste tyres.

Although it is difficult to ascertain how many spent tyres are available in South Africa currently, it would appear that there are approximately 10 million tyres, or about 75 000 tonnes [Risk Management, p. 7] of tyre material available annually. About 1.2 million tonnes of coal is currently used by the South African cement industry, and about 25% of this could be replaced by tyres. The currently available volume of spent tyres equates to about 154 tonnes of coal per day (1kg of rubber = 33 mega-Joules (mJ) of energy while 1kg of coal offers about 27 mJ [ibid]), while 25% of 1.2 million tonnes of coal is 672 tonnes per day. The PPC EIA BID speaks of saving 150 000 tons of coal per annum, but the available tyres equate only to 56 000 tons of coal. This means that the balance of 94 000 tons of coal will, presumably, come from other wastes or imported tyres.

PPC, in their sustainability report for the year ended 30 September 2005, places some stress on the fact that tyres could be used to replace coal, and on the negotiations which have been taking place between DEAT and players in the tyre and cement industries [W12]. It would appear that at this point PPC intend to run a "secondary materials co-processing programme" at six sites [PPC BID] in 12 kilns. Holcim has two kilns, while Lafarge has one kiln. This makes fifteen kilns in all which potentially could burn tyres. It should be noted that the cement industry is likely to be the only industry able to successfully burn tyres because of the very high temperatures reached in the kilns, and that they are therefore likely to be the only viable "tyre derived fuel users" in the country.

The current kilns would need to be modified in order to burn tyres. This will cost between 18 and 25 million Rand per kiln [Furter]. The draft Memorandum makes provision for an establishment subsidy of R0.38/kg to be paid to the users of waste tyres. Assuming 75 000 tonnes of waste tyres, this equates to 28.5 million Rand per annum, or 142.5 million Rand over the five years for which the establishment subsidy will be made available. In addition, there will be a disposal fee paid to the users of spent tyres. This fee is subject to tender. The monies that fund these fees will come from a "green" levy which will apply to all new tyres sold. In other words, the consumer of new tyres could conceivably land up funding the cement industry's kiln upgrades, and subsidising their fuel costs.

Given that the number of spent tyres available in South Africa is considerably less than the number of tyres which could be burned by the cement industry, and that the number of tyres burned would increase the amount of money available from both the establishment subsidy and the disposal fees, it seems almost inevitable that, should kilns be allowed to burn tyres, tyres will eventually be imported for this purpose.

It is interesting to note that the draft "Waste Tyre Regulation", which was expected to be published for comment in August 2006, has been delayed (again – it was initially expected in August 2005) until March 2007. It is thought that this is because it would be expedient for the mooted Incineration Regulation to come out first.

The cement industry suggests that the use of tyres as a fuel is beneficial to all. In the PPC BID we are given a dramatic set of pictures to convince us that a tyre will be completely destroyed in six seconds, and are led to believe that virtually nothing will be emitted as a result [p. 15]. Research performed by Carrasco et al. indicated, however, that while there were improvements in some areas, the emission of some pollutants was exacerbated by the inclusion of tyres.

Amount of pollutants emitted to the atmosphere through the stacks per kilogram of clinker produced before and after the scrap tire valorisation.
Carrasco et al (2002)

	Coal			Coal and tyres		
Pollutant†	**Kilns**	**Cooling units**	**Total**	**Kilns**	**Cooling units**	**Total**
PM, mg/kg	166.4	86.5	252.9	177.4	112.4	289.8
Metals, μg/kg						
Fe	1464.6	1309.2	2773.8	2741.3	1717.4	4458.7
Al	1250.2	1422.5	2672.7	1950.1	1612.8	3562.9
Zn	310.5	91.6	402.1	2245.8	114.2	2360.0
Pb	202.7	21.7	224.4	477.6	31.0	508.7
Cr	80.5	22.0	102.5	422.5	28.0	450.5
Hg	92.4	0.85	93.3	71.2	1.5	72.7
Mn	46.1	39.4	85.5	122.9	48.6	171.5
Cu	6.6	5.9	12.5	15.9	5.8	21.7
Gases, mg/kg						
NO_x	2943.4	–	2943.4	2628.3	–	2628.3
SO_2	1169.0	–	1169.0	1446.7	–	1446.7
CO	260.7	–	260.7	356.0	–	356.0
HCl	16.4	–	16.4	24.4	–	24.4
Organics, μg/kg						
PAH	143.0	–	143.0	123.6	–	123.6
Naphtalene	130.7	–	130.7	120.4	–	120.4
Chlorobenzene	2.9	–	2.9	1.9	–	1.9
Dioxins and furans	0.0017	–	0.0017	0.00094	–	0.00094

† PM = particulate matter; PAH = polycyclic aromatic hydrocarbons.

Clearly, emissions from a kiln will vary with exactly what is being burned, and there would never be a standard emission pattern for all kilns, or even for one kiln at all times.

The industry generally characterises the burning of waste in cement kilns as "an internationally accepted practice". But, in 2003 in Mexico less than five percent of fuel used was alternative fuel, even though all cement kilns in Mexico are licensed to burn waste, while alternative fuels accounted for eight percent in Canada and nine percent in the United States [Commission for Environmental Co-operation, p. 36]. Should the practice, in fact, be "accepted", then it is unlikely that there would be as many organisations militating against the use of such fuels as there are[2].

In South Africa there is currently a push from both Pretoria Portland Cement (PPC) and Holcim to get permission to burn waste in their kilns. Holcim put in EIAs for both their plants, located in Lichtenberg, in the North West Province, and Ulco in the Northern Cape Province, in 2003. The Lichtenberg EIA was refused, on the basis of the precautionary principle. The RoD [North West

[2] These organisations include CANK (Campaign Against the New Kiln), Wiltshire Friends of the Earth and No To Cemex in the United Kingdom; Downwinders at Risk, Blue Skies, MATB (Montanans Against Toxic Burning), South Camden Citizens in Action, Friends of Hudson and the National Citizens Cement Kiln Coalition in the United States; Sierra Club and Earth Justice in Canada; Association Paillons Environment in France; Greenpeace in Spain; JA! in Mozambique.

RoD] also points out that the EIA did not address potential cumulative impacts, was not clear on the type of wastes to be used, did not properly evaluate the potential health impacts, did not look at the "no-go" option and that the emission data included was not based on either actual emission measurements, or on mass balance estimates from similar plants. The RoD from the Northern Cape Province [Northern Cape RoD], however, granted authorisation to Holcim to burn waste derived fuels. This authorisation was appealed by groundWork [Peek, 31 March 2006], on the basis that the decision had been made in a national policy vacuum, which resulted in a lack of cohesion between decisions being made in different parts of the country, that the health effects are potentially serious and that the EIA was undertaken on the wrong process. groundWork contended that the EIA should be focused on how best to handle hazardous waste rather than on whether a cement kiln should burn hazardous waste. Initially, Mr Saaiman decided that, due to the technical complexities, the lack of policy and the newness of the procedures, he was unable to finalise the matter [Abrahams, 21 June 2006]. This decision was, however, unmade in a further letter, where the appeal was set aside on the basis that the grounds of the appeal were without merit [Saaiman, 6 September 2006].

In 2006, Pretoria Portland Cement (PPC) began their EIA process. While it is still unclear as to exactly what is going to happen, it appears that they are aiming at a single, blanket EIA for all their kilns (as exists in Mexico), although they have begun a process of open days in each province. At the first open day, held in Hercules, Gauteng, on 7 September 2006, Ben Mazibuko from groundWork was variously told that they were doing six separate EIAs and that they were hoping to do only one EIA. Whatever the truth might be, in their operational review for the year ended 30 September 2005, PPC say:

> "The success of secondary materials and alternative waste solutions was limited to the Spent Pot Liners (SPL) contract and some ad hoc waste burn trials. The new legal requirement for environmental impact assessments (EIA) to be concluded before any permits can be issued has slowed progress. A project to obtain an "umbrella" EIA for typical generic waste streams for all operations is under way." [W14]

Arguments against perceived benefits, as presented in the PPC EIA BID, of the co-processing of secondary materials

The PPC EIA BID outlines the following benefits of burning waste. As these are very similar to the arguments used by all cement companies, they can be seen to represent the industry's arguments.

1. **Conservation of a non-renewable resource**
   Substituting coal with unwanted materials that require disposal could save up to 150 000 tons of coal per year.
   This would imply that waste is a renewable resource, which it certainly should not be. In the waste hierarchy, energy recovery is regarded as being the second least desirable manner in which to handle waste, after simple disposal [W15]. Any process which is dependent on a constant (and in this case, large) stream of waste is essentially unsustainable.

2. **Energy recovery from waste materials**
   It has been found that waste incinerators are less efficient than cement kilns for incineration of waste. It is preferable to use the waste energy as a resource (i.e. secondary fuel). Furthermore, it reduces the need for construction of new waste incinerators.
   While it is no doubt true that it is better to reclaim the energy than simply send it up a stack, the argument is premised on the false idea that burning waste is a necessity, which it is not. Also, the energy required to produce the waste is often greater than the energy recovered, and the difference between energy used to create the original item and the energy recovered

is greater than what would be required to recycle it. For example, approximately 55 000 BTU are needed to produce a pound of rubber, but the energy value of a tyre used for fuel is about 14 000 BTU. Converting a pound of waste tyre into good quality granulated or crumb rubber needs about 1 000 BTU [W16]. In hard terms, therefore, it would be more correct to say that, rather than 14 000 BTU being recovered, 54 000 BTU are being wasted when tyres are used as fuel rather than re-cycled.

3. **Increased environmental performance**
   [C]ement kilns offer improved incineration efficiency with reduced environmental impact due to high temperature, long residence times, high turbulence, high pH environment, thermal stability and the elimination of ash residues. In addition, the kilns can accept sufficiently large quantities of waste to provide a viable alternative to landfilling and conventional incineration.
   Once again, the premise is that incineration is inevitable, which it is not.

4. **Waste minimisation**
   The combustion of waste materials will contribute to the implementation of the National Waste Management Strategy in South Africa.
   Given that the word "incineration" and its derivatives are used only 24 times in the 151 pages of the strategy and this generally in relation to medical waste, which is not one of the waste streams being considered by the cement industry, and that the strategy says "[s]ince incineration of general waste with efficient air pollution control is an expensive treatment method, even with heat recovery, it will not be promoted" [DEAT, p. 100], this appears to be a little disingenuous.

5. **Conservation of natural resources**
   Firstly, by the use of combustible materials as a substitute for coal; and secondly, the mineral component of the waste materials, such as ash, is incorporated in to the final cement product and may replace some raw materials.
   This means essentially the same as the first three points, although it does add the concept that some waste may be incorporated into the cement, which introduces its own concerns.

6. **Reduced overall greenhouse gas emissions**
   By co-processing of waste, no new emissions are generated, but rather "take over" emissions from conventional incinerators. Therefore there is an overall decrease in greenhouse gas production if the emissions from incinerators and landfills are considered.
   Once again, this point is based on the idea that the waste will, one way or another, be burned, so it might as well be burned by cement kilns. This is a false premise.

7. **Reduced risk of soil and groundwater contamination**
   Potentially hazardous waste materials will be incinerated instead of stored in landfills, as well as reduced land requirement for landfills.
   Apart from being ungrammatical, this argument is also falsely premised on the idea that there are only two things to do with waste – burn or send to landfill.

8. **No significant change in emissions**
   No significant change in emissions is expected, if the basic rules of secondary materials and raw material usage are observed, (feeding via the correct firing path, correct storage, using trustworthy sources & setting limits on quality). In some cases, considerable improvements can even be expected.

There is some evidence to suggest that emissions are, indeed, largely limited under perfect conditions. However, perfect conditions rarely persist, and during start-up and shut-down situations, as well as upsets during normal operation, emissions have been shown to be problematic [Carrasco, et al.].

Holcim have also lodged an EIA for a blending plant, to be located in Gauteng. Blending plants take waste and create fuel products. Some of these products are known as SLFs (Secondary Liquid Fuels) and are given fancy names, such as Cemfuel, which is produced by Castle Cement affiliate company in Britain. Castle had hoped that, once waste had been turned into Cemfuel, it could be classed as a fuel and would therefore no longer be seen to be waste. This would mean that it would not be subject to the trade restrictions imposed upon waste through mechanisms such as the Basel Convention [W17]. This hope, however, was, for the moment at least, dashed in a court case where the judge deemed that Cemfuel remained waste until such time as it was burned and the energy recovered [W18].

Over and above any concerns about what may be emitted from the stack when wastes are burned, or what may be incorporated into the cement itself, the use of waste in cement kilns also results in the transport of this waste to the blending plants and kilns, the storage of this waste at the facility, and the handling of this waste by cement workers.

Greenhouse gas emissions

According to the cement industry itself, it is responsible for about 3% of the world's total greenhouse gas emissions and for 5% of CO_2 emissions [Humphreys and Mahasenan, p. 2]. This equates to about 1.4 Gt (1 Gt = 1 gigatonne = 10^9 metric tonnes = 100 000 000 tonnes [W19]). These emissions come from the burning of fossil fuels in kilns (40%), transport of raw materials (5%), fossil fuels required for electricity (5%) and the conversion of limestone ($CaCO_3$) to calcium oxide (CaO) (50%). These are estimates, however, as the cement industry does not collect this data in a systematic manner [Humphreys and Mahasenan, p. 4].

Japan has managed to reduce their CO_2 emissions to .73kg CO_2 for each kilogram of cement produced, the best CO_2 emission record for cement kilns in the world but, having made great improvements with their early efforts, have been unable to further reduce them. Similarly, cement factories in Britain showed sharp improvement when first addressing the problem in the 1990s, but a levelling off in 2003 and 2004 [British Cement Association, p. 1]. It is felt that only fundamental technology breakthroughs or changes in market incentives will allow for further meaningful reductions in emissions [Humphreys and Mahasenan, p. 4].

The industry uses the potential reduction of CO2 emissions as a reason for the use of waste derived fuels. However, given that half of the CO_2 emissions result from the calcification of limestone, changes in fuel will have no impact on these particular emissions, and even if the industry were to be able to reduce their fuel related emissions of CO_2 to nothing, they would still be responsible for more than 2.5% of the world's total CO_2 emissions – or round about 84 million tonnes every year.

Mercury emissions

Mercury is classified as a persistent, bioaccumulative toxic (PBT) chemical. It can cause neurological and developmental problems, particularly in children.

In a letter to the United States Environmental Protection Agency, protesting the fact that the EPA had elected not to place limits on the mercury emissions of cement kilns, the group Physicians for Social Responsibility explain the effects of mercury pollution as follows:

> "Mercury is a serious threat to public health**.** The health effects of exposure to mercury pollution are well documented. Methylmercury, an organic form of mercury that bioaccumulates in a number of fish and marine mammal species commonly eaten by humans, is known to be highly toxic and can adversely affect several organ systems, including the cardiovascular system, and especially the brain and central nervous system.
>
> The nervous systems of children, infants, and above all the developing fetus are the most sensitive to mercury exposures. Methylmercury easily passes via the placenta from mother to fetus, where it readily penetrates the fetal brain. Neurological and development impairment can occur from both high dose and low dose exposures during fetal development. High dose exposures have been demonstrated to result in low birth weight, severe mental retardation, small head circumference, cerebral palsy, deafness, blindness, and seizures. Low dose exposures can result in lowered IQ, decreased performance on tests of attention, fine motor function, and language, and developmental delays, such as delayed walking. Such effects can take place even at exposure levels where the mother remains healthy or suffers only minor symptoms due to mercury exposure.
>
> Mercury pollution is ubiquitous. In its assessment of the toxicological effects of methylmercury, the National Research Council concluded that mercury is both widespread and persistent in the environment.[11] According to the National Listing of Fish Advisories (NLFA), 2,436 mercury advisories were issued by 44 states, 1 territory, and 2 tribes and a total of 13,183,748 lake acres and 765,299 river miles were under advisory for mercury in 2004.[12] Additionally, Oklahoma, one of the six states not listed on the 2004 NLFA (along with Alaska, Iowa, Kansas, Utah, and Wyoming) issued a statewide mercury advisory after the time of data release, bringing the total number of states under mercury advisory in 2004 to 45. Also, in 2005, the State Departments of Health and Environmental Quality, the Division of Wildlife Resources, and the U.S. Fish and Wildlife Service (FWS) in Utah jointly issued a no-consumption advisory for two duck species found to have toxic levels of mercury in their flesh.
>
> This pervasiveness of mercury contamination in the environment presents a serious health risk to those who eat contaminated fish, marine mammal, and wildfowl species. In January 2003, the Centers for Disease Control and Prevention (CDC) found that nearly eight percent of women of child bearing ages (16 to 49) are exposed to levels of mercury that exceed the EPA reference dose (RfD) considered safe for a fetus—0.1 micrograms per kilogram (μg/kg) of body weight per day and 5.8 micrograms per liter (μg/L) of blood. A more recent analysis by EPA scientists raised that estimate to more than 15% of women, based on peer-reviewed studies showing that cord blood concentrates mercury at significantly higher levels than maternal blood. Using 2000 census data to extrapolate across the entire U.S. population, this could mean that as many as 630,000 newborns each year are at risk of serious congenital neurological and development impairment."

In Northern America in 2003, cement kilns, which represent less than one percent of industries reporting, reported about nine percent of the total mercury released in air emissions [Commission for Environmental Co-operation, p.56] in North America. This equates to approximately 5.75 tons of mercury and mercury compounds, about 5.23 tons of which were emitted to the air.

In view of the high and unregulated emissions, Physicians for Social Responsibility calls on the EPA to more stringently monitor cement kiln stacks. The letter also suggests that the reporting methods used by the cement kilns are flawed, and that the actual emissions from these kilns may be significantly higher.

Controlling mercury emissions from cement kilns is particularly troublesome as the high temperature of the kilns makes it impossible to use the bag houses used in other industries. A bag house traps dust from the boiler and an activated carbon injection system is used to extract the mercury. The bags would melt in a cement kiln environment, and carbon injection is not effective where there is a lot of dust. Luc Robitaille of Holcim cement says that there is no technology that exists in the cement industry to control mercury emissions [Dan Shapley, 16 July 2006].

Dioxins, Furans and products of incomplete combustion

In the PPC BID it is stated "When using secondary materials during the cement manufacturing process, more than 99% of carbonaceous compounds end up as innocuous combustion gases, namely carbon dioxide and water vapour. Carbon monoxide formation is carefully controlled during normal kiln operation, and this will also ensure complete combustion of secondary materials" [p15]. Even assuming this to be completely true (and not everybody regards CO2 as a completely innocuous gas), we are left with a small percentage of compounds which don't end up as innocuous gases, and the fact that the statement holds true only under normal kiln operation.

Dr Neil Carmen, a well known anti-incineration advocate, questions whether cement kilns really do provide long enough residence times and sufficient oxygen to give complete combustion. He says that when cement kilns are stack tested they still show products of incomplete combustion (PICs), which demonstrates that perfect combustion is not being achieved. He also suggests that the very large volumes of solid materials which are fed into the kiln may result in less turbulence than is suggested by the industry, and that combustion will therefore be compromised. He says that, because heating air uses energy, cement kilns run on the lower limits of excess air required for good combustion. He suggests that when stack tests are performed, the cement industry will run at higher excess air than normal, control the kilns more carefully, stop solid ring formation (which occurs, for example, when chlorine bearing materials are burned and the gases released form a temporary blockage in the kiln) and generally operate more carefully than they would normally do [W20].

Dr Carmen also comments that cement kilns are not designed to have major fail-safe devices, as purpose-built incinerators are required to have, and that upsets in the manufacturing process can therefore result in dangerous emissions.

Combustion upsets are par for the course in any kind of kiln or incinerator. Because of the very hot raw mix, a cement kiln must run through each combustion upset or process malfunction. This means that it is possible for the cement kiln to contain products of incomplete combustion, even though, as is pointed out in the PPC BID, they are required to stop feeding new matter into the kiln should there be an upset [p13]. This presents a real risk to surrounding communities as upset emissions have been shown to be more toxic than the original waste being burned through the creation of harmful products of incomplete combustion [Neil Carmen, 23 April 2004].

Dioxins and Furans are inadvertently created through combustion and industrial activities and are considered to be persistent, bio-accumulative toxic compounds. Some are carcinogenic and are suspected to be neurological, developmental and reproductive toxicants or endocrine disruptors. They may be produced when exhaust gases cool, and cooling these gases quickly through the critical temperature range of 450 to 200°C has been demonstrated to reduce dioxin and furan formation in cement kilns [Commission for Environmental Co-operation, p. 60].

In 1995, at an EPA workshop, it was indicated that the cement industry was responsible for 17% of all dioxin emissions in the United States, and that those kilns burning hazardous waste were responsible for 99% of the cement industry's dioxin emissions [W21], and in 1998, in their report "The inventory of Sources of Dioxin the United States", they say that kilns that burn hazardous waste have 80 times higher dioxin emissions in the stack gases than those which use only conventional fuels [USEPA, p. 5]. In addition, USEPA also reports that dioxins are found in the Cement Kiln Dust (CKD) of both kilns which burn conventional fuel and those that burn hazardous waste, but that concentrations of dioxins in the CKD of those burning hazardous waste are almost 100 times greater than those not doing so.

In an extraordinary piece titled "A Review of Dioxin Emissions in Cement Kilns" [W22], David Gossman, a cement kiln apologist, makes the extraordinary assertion that dioxins have been released through natural fires forever, and that, in the scale of things, cement kilns are not major emitters of dioxins. What he does not appear to have taken into account, however, is that the nature of the dioxins released through anthropogenic activities, especially activities involving the combusting of varieties of compounds together, are likely to be very different from those released naturally.

In 2005, Castle Cement stopped operation of their Kiln 3 at Padeswood when the Welsh Environment Agency served an enforcement notice on them for a breach of dioxin emission levels. This kiln was actually due to close down shortly, as the brand-new replacement, Padeswood Kiln 4, was shortly to come on line [W23]. In March 2006 they were ordered to pay a fine of 99 thousand pounds [W24].

Ozone

Ozone (O_3) is "good" when it is high up in the atmosphere, in the region known as the stratosphere, but "bad" when found close to the earth in the troposphere [W25]. Too much ozone can cause respiratory problems in humans. The electrostatic precipitator (ESP) is a particulate collection device that removes particles from air or flowing gas through the force of an induced electrostatic charge, and which tends to create ozone [W26]. A study showed that maintenance workers who suffered from respiratory and eye irritations when working in a cement kiln were being affected by the ozone being generated by the ESP [W27].

In 2004, two activist groups, Downwinders and Blue Skies, Midlothian citizens groups which have long been fighting the three enormous cement factories in Texas, sued the US Environmental Protection Agency (USEPA) "to do its job", and force the cement factories to reduce their emissions, especially ozone which is thought to be causing the extremely high incidence of asthma in the areas downwind from the plants [W28]. A settlement was reached in 2005 whereby a cement kiln study would be conducted. This study concluded that emissions, including ozone, could be considerably reduced through the installation of new technology known as selective catalytic reduction (SCR). This is, however, quite expensive and the cement industry, who generally deny that their plants are any sort of problem at all, are resisting the installation of SCRs.

Cement Kiln Dust (CKD) and Particle emissions

Dust emissions are one of the primary problems faced by the cement industry. However, according to industry, these emissions "have been reduced considerably in the last 20 years, and state-of-theart abatement techniques now available (electrostatic precipitators, bag filters) result in stack emissions which are insignificant in a modern and well managed cement plant" [CSI, January 2006, p. 47]. This statement not withstanding, a continuous monitoring system run by the NGO Emission-Watch, at Castle Cement's brand-new plant at Padeswood in Flintshire, North Wales, indicates frequent upsets where particulate matter exceeds the regulatory limit of 50µg/m3 [W29].

Most materials which are burned at very high temperatures will vaporise. However, when this vapour is cooled, the aerosols could have changed from the original materials to a previously unknown compound, which might have unpredictable consequences for people's health and for the environment. Even materials that are generally considered to be chemically inert may become reactive and electrically charged when they are changed into small particles and at times these particles may be of a novel configuration [W30].

Particles are classified by size. Anything of a size less than PM10µm cannot be resisted by humans or animals, and can be breathed in. When substances are vaporised they can re-condense into much smaller particles, and these can be absorbed into the body through the wall of the lung. Tiny particles in the air which settle on fruit and vegetables, or which have been absorbed by animals, can be taken into our bodies when eaten by us. When breathed in, these particles would tend to cause respiratory problems and may be implicated in diseases such as lung cancer and emphysema. As they are sometimes made up of toxic material, or could even be some brand-new compound, ingestion of such particles in any manner might be dangerous [W31].

Large amounts of fine material are given off during the cement making process. This material is carried out of the kiln by the flow of hot gas generated inside the kiln, and is not incorporated into the clinker as the raw materials have not been fully processed. This dust, CKD, therefore becomes a waste by-product [W32]. In many cases, CKD is recycled back into the kiln and is ultimately incorporated into the clinker. The problem with this is that heavy metals can become concentrated in the CKD as some of it will pass through the kiln many times [W33]. Where it is not recycled, it is stored in piles at the facility, and ultimately transferred to landfill. There have been allegations that this dust has contaminated both surface and ground water, but an USEPA report to congress [W34] tends to discount these (as it does most issues). None the less, the report does accede that the risks associated with CKD are "generally low, however, there is a potential under certain circumstances for CKD to pose a danger to human health and environment, and it may do so in the future."

The report does not directly compare CKD from kilns using conventional fuels and those burning waste, but does say "(o)verall, certain metals appear to be present at a consistently higher mean concentration in CKD generated by kilns burning hazardous waste than in CKD generated by kilns not using this type of alternative fuel. Lead, cadmium, and chromium are the most prominent examples." The report indicates that CKD from kilns burning hazardous waste contains on average 9 times more lead, 5 times more cadmium, and 7 times more chromium than kilns which use traditional fuels.

The study by Carrasco et al. showed that emissions of particulate matter go up when tyres are burned along with coal, rather than when coal is burned alone.

A study of 2498 cement workers employed at a cement factory in Lithuania indicated significantly increased standard mortality ratios for all malignant neoplasms and for lung cancer in males. It was found that the longer the exposure to the cement dust, the higher the risk of an increased risk of lung and stomach cancers amongst men, although the risk was not increased amongst females [Smailyte et al.].

Research done in the Rhein-Neckar region of Germany concluded that there is good evidence that cement dust exposure is an independent risk factor (after tobacco, alcohol and asbestos have been factored out) for laryngeal carcinoma. A significant odds ratio was demonstrated for persons, such as construction workers, who were exposed to cement in the course of their work [Deitz, et al.].

Another study performed in Pakistan on cement mill workers concluded that exposure to cement dust causes interstitial lung disease, pleural thickening and chronic bronchitis [Meo, 2003]. A linked study indicated that exposure to cement dust causes increased mean values of the total leukocyte count and the erythrocyte sedimentation rate. Interestingly, this increase does not appear to be related to the length of exposure to the cement dust [Meo et al. (a), 2002]. A previous study performed by the same team came to the conclusion that exposure to cement dust both impairs lung function and affects costal muscle performance [Meo et al. (b), 2002].

A study conducted in Korea found that the prevalence of preterm delivery of babies was significantly higher in mothers living within zero to two kilometers of a Portland Cement plant, than in mothers living two to four kilometers away [Yang, et al.]. They note that the cement industry is the main source of particulate air pollution in Kaosiung city, where the study took place.

Off-gassing

Various chemicals are sometimes added to the cement or concrete mixes which can, conceivably, off-gas small quantities of formaldehydes or other chemicals into the air. Manufacturers are not always forthcoming regarding which chemicals are added so one cannot always know what might be released and this could prove problematic to sensitive individuals, especially indoors [W35].

In addition, it is currently unknown what the effects of incorporating the combusted waste matter will have. Conceivably some of these, too, may off-gas. And certainly, when the cement is used, or the concrete or mortar for which it has been used is later broken up, it is more than possible that contaminants will be "set free".

Products

As the residues from the fuel which is used to fire the kiln are ultimately incorporated into the clinker, the clinker and cement produced from the clinker will obviously contain the same types of metals and organic compounds which are found in the CKD and in the air emissions [W36].

Concern has been expressed as to whether cement produced by kilns which burn alternative fuels will contain unacceptable levels of metals. It is possible that, should metals be present in great enough quantities, the integrity of the cement could be threatened. It is also possible that these materials could leach out from the finished cement, or could be released when the cement is later broken up for whatever reason.

While researching their Cement Kiln Dust Report, the EPA found that some clinker samples from waste burning kilns contained certain materials in quantities which exceeded the Land Disposal Restrictions for hazardous waste. This means that this clinker could technically be considered hazardous waste. Other research, however, has indicated that there is very little difference between the concentrations of metal in cement produced by kilns burning hazardous waste and those not doing so [W36]. It should be remembered, however, that what is being burned at any one time will impact on what is incorporated into the cement.

There are many inferences that cement quality is negatively impacted by the burning of hazardous waste, but an extensive search of the internet has not produced any information which categorically bears this out. An interesting case was reported early in 2005 [Parker], where Lafarge admitted to having faked cement quality data for more than two years, resulting in them having supplied over 1 Mt of cement which was too alkaline for safety into the building industry. Lafarge blamed "rogue employees" for having made up the data, and said that the reason for the problem was that they had started using chalk, a major raw material, from a new quarry. However, it is believed that the time period over which the data was faked coincides with the period over which the plant burned tyre crumb [Wallis].

Conclusion

While the industry has spent a great deal of time, energy, money and imagination on putting a positive spin on the production of cement, there are a number of issues which pose serious problems for the industry, for the people who live near the manufacturing plants and the people who ultimately use, or are surrounded by, cement products.

Even without the introduction of alternative fuels to the scenario, industry emissions are problematic and, while there is as yet little firm data to back this up, it is probable that the burning of hazardous waste will introduce additional concerns.

Holcim and GTZ (Deutsche Gesellschaft fur Technische Zusammenarbeit) have produced an extensive document titled "Guidelines on Co-processing Waste Materials in Cement Production", which seeks to outline the ideal conditions under which waste could be burned in cement kilns. While it appears to make very proper recommendations, it is quite clear that few of the ideal conditions exist, even in Europe, let alone in South Africa. Lafarge have teamed up with WWF (World Wildlife Fund), and have together set goals for the cement plants which Lafarge owns all over the world. These include CO2 reductions as well as the rehabilitation of quarries [W38]. It is unfortunate that organisations such as these should engage with the cement industry in this manner as these kinds of projects serve to legitimise what the cement industry is doing. On the other hand, it also does provide some sort of basis from which civil society can work.

Through burning waste, cement kilns become simply incinerators in disguise. Even though this is so, cement kilns are generally not subject to the same stringent emission standards that waste incinerators are. This is clearly an unreasonable situation as it not only means that cement kilns are in a position to pollute the community with relative freedom, but also that they have an unfair competitive advantage over the incinerators which, no matter how we may view them, are at least required to remain within certain standards.

In South Africa, a lack of policy around the management of waste, and of hazardous waste, creates a vacuum in which it becomes possible for the cement industry to subvert the intention of the law as it currently stands. PPC, for example, are seeking to submit a single EIA which grants them permission to burn certain streams of waste at all their kilns. The bases on which they are doing this are probably that all waste streams will have a similar effect and that the local authorities do not have people sufficiently skilled to properly evaluate the EIAs. Clearly, each kiln location has a different set of parameters, and issues beyond the actual waste streams need to be addressed in individual EIAs. To allow a single EIA goes against the principle of the process, which is to assess potential impacts on individual environments.

However, the use of waste in kilns represents for the industry the kind of operating savings which will make an appreciable difference to their bottom line – assuming that they do not intend to pass these savings on to the consumer – or to their ability to be competitive in the market, and it is likely that, as in the rest of the world, the industry in South Africa will pursue permission keenly.

The key elements of the industry argument is that it is better to burn waste in a cement kiln than in a conventional incinerator as they burn hotter and for longer, they exist already, and the energy from the waste is "recycled". These are fallacious but, in the absence of a clear national policy and of a proper plan for genuine recycling, they are likely to carry weight with both communities and government.

Ideally, the making of cement would be phased out altogether, although this is clearly a long-term option and would require a great deal of innovation and imagination from the industry and from society in general. In the short-term, however, communities should be pushing for more stringent standards to be imposed upon the industry, and for the burning of waste to be disallowed completely.

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