The Impact of Cement Kilns on the Environment

By Jane Harley

Briefing Paper 2007

groundWork

CONTENTS

INTRODUCTION

Concrete, a vital element of which is cement, is the second most consumed substance in the world. Only water is used in greater quantities [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.

The Cement Sustainability Initiative, representing more than 50 percent of the cement manufacturing capacity outside of China, 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 CO2 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 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.

RESEARCH METHOD

The three major cement producers in South Africa are all currently running Environmental Impact Assessment (EIA) processes in order to be allowed to burn waste in their cement kilns. 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. Traditionally, controls and abatement technologies which would be used in Europe or America are often not put in place in developing countries. In addition, even if there were sound laws in place in South Africa, enforcement of these laws has always been problematic.

Because groundWork is opposed to any form of incineration, and is concerned about the management (or lack of management) of hazardous waste, it was felt that research into the industry, particularly regarding the burning of hazardous waste, was necessary.

Research for this report was almost entirely desk based, and information was primarily derived from the internet. While there are a number of references on the internet which extrapolate information gained from studies of incinerators to cement kilns, there are not, in fact, very many studies directly related to cement kilns. For the purposes of the report, however, only information which was unambiguously related to cement kilns was used.

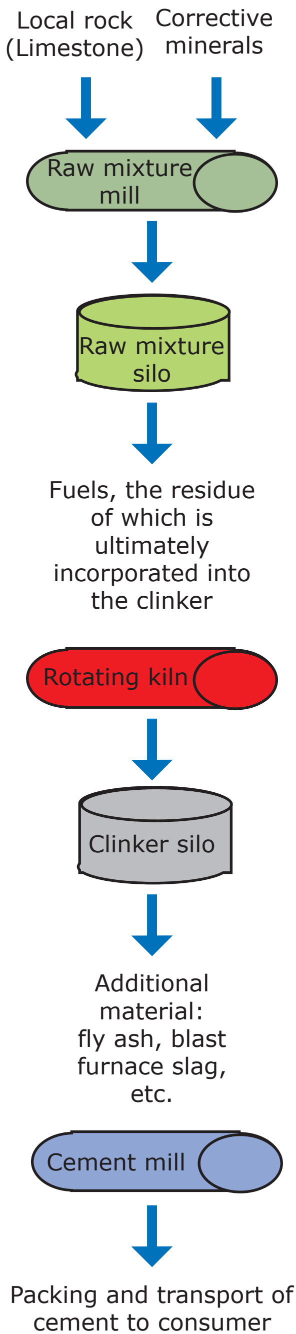
RESEARCH RESULTS

The manufacturing of cement creates a number of environmental problems.

Energy and Fuel

To make cement, limestone is turned to clinker. Because this process requires high temperatures, between 1400°C and 1500°C, the cement industry is one of the most energy intensive industries,

The Cement Making Process



consuming about ten 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 [W06], 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].

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 [ibid, 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[1].

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,

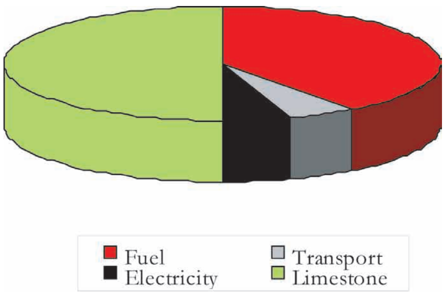
[1] These organisations include CANK (Campaign Against the New Kiln), Wiltshire Friends of the Earth and No To Cemex in the United Kingdom; Downwinders at Risk, Blue Skies, MATB (Montanans Against Toxic Burning), South Camden Citizens in Action, Friends of Hudson and the National Citizens Cement Kiln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

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 [W07]). 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].

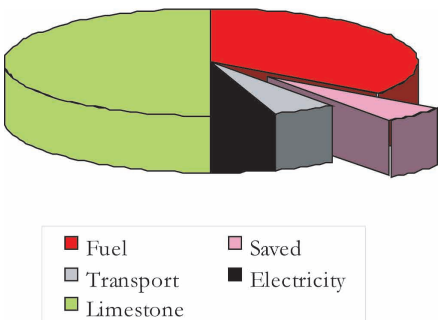
Current greenhouse emissions



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.

Projected greenhouse gas savings if alternative fuels are used



Mercury emissions

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

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.

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 [Shapley, 16 July 2006].

Dioxins, Furans and products of incomplete combustion

The industry often makes statements like "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" [PPC BID, p15]. Even assuming this to be completely true (and not everybody regards CO2 as a completely innocuous gas), we are still 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.

Castle Cement's filter and cooling tower at Padeswood. Dioxins and Furans 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]. Picture from www.castlecement.co.uk.

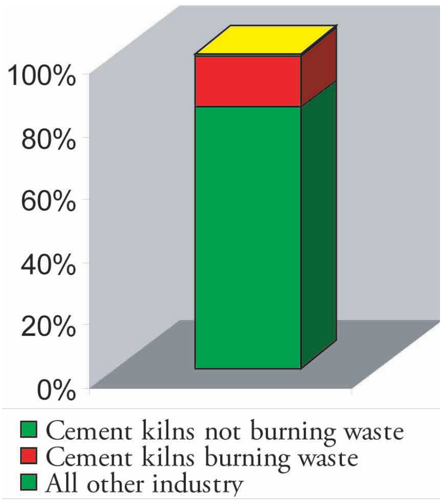
Dr Neil Carmen, a well known anti-incineration advocate, questions whether cement kilns really do provide long enough residence times and sufficient oxygen to give complete combustion. He says that when cement kilns are stack tested they still show products of incomplete combustion (PICs), which demonstrates 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 [W08].

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 they are required to stop feeding new matter into the kiln should there be an upset [PPC BID, 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 [Carmen, 23 April 2004].

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 [W09], 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.

The cement industry's contribution to Dioxin emissions



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 [W10]. In March 2006 they were ordered to pay a fine of 99 thousand pounds [W11].

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 [W12]. 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 [W13]. 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 [W14].

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 [W15]. 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-the-art 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 [W16].

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 [W17].

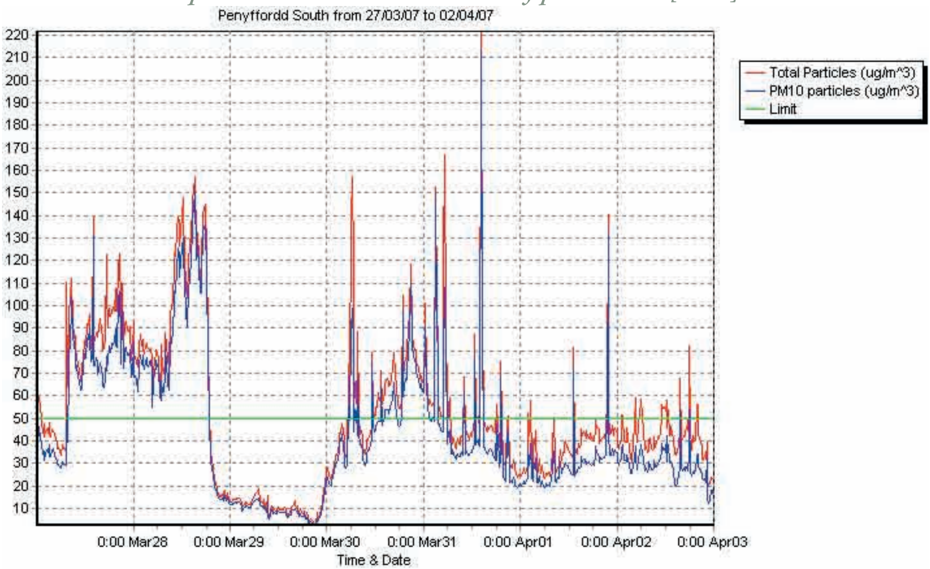
Particles are classified by size. Anything of a size less than PM10µm cannot be resisted by humans or animals, and can be breathed in. When substances are vaporised they can re-condense into much smaller particles, and these can be absorbed into the body through the wall of the lung. Tiny particles in 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 [W18].

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 [W19]. 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 [W20]. Where it is not recycled, it is stored in piles at the facility, and ultimately transferred to landfill.

An USEPA report to congress [W21] 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. There are a number of studies which indicate that exposure to CKD increases the risk of lung, stomach and laryngeal cancers [Smailyte et al., Deitz, et al.] and lung diseases [Meo, 2003, Meo et al. (a), 2002, Meo et al. (b), 2002]. It has also been implicated in the birth of preterm babies [Yang, et al.].

On-going monitoring at Padeswood Kiln indicates that despite state-of-the-art technology, particulate emissions are still very problematic [W16]



The Padeswood kiln was flushed on 27 March 2007. This is reportedly a frequent occurrence, despite Castle Cement's assurances that the problems have been addressed. Picture from www.cank.org.uk.

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 [W22].

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 [W23].

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.

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.

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.

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 if they do.

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 arguments.

Ideally, the making of cement should 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.

Alternative building methods include using straw and cob, which includes mud and stone

REFERENCES

Carrasco, F., Bredin, N., and Heitz, M. 2002. Atmospheric Pollutants and Trace Gases – Gaseous Contaminant Emissions as Affected by Burning Scrap Tires in Cement Manufacturing. Journal of Environmental Quality. 31:1484–1490.

Commission for Environmental Cooperation. 2006. Taking Stock: 2003 North American Pollutant Releases and Transfers. Canada: Communications Department of the Secretariat of the CEC

CSI. 2006. Formation and release of POPs in the Cement Industry (2nd Edition). Sintef.

Dietz, A., Ramroth, H., Urban, T., Ahrens, W., Becher, H. 2004. Exposure to cement dust, related occupational groups and laryngeal cancer risk: results of a population based case-control study. International Journal of Cancer 108(6): 907

Humphreys, K and Mahasenan, M. 2002. Towards a Sustainable Cement Industry – Substudy 8: Climate Change. World Business Council for Sustainable Development: Cement Sustainability Initiative.

Meo, S. 2003. Chest radiological findings in Pakistan cement mill workers. Saudi Medical Journal, 24: 287-190

Meo, S., Azeem, M., Arian, S., Subhan, M. 2002. Hematological changes in cement mill workers. Saudi Medical Journal, 23: 1386-1389

Meo, S., Azeem, M., Ghori, M., Subhan, M. 2002. Lung function and surface electromyography of intercostals muscles in cement mill workers. International Journal of Occupational and Environmental Health, 15: 279-287

PPC. 2006. Environmental Impact Assessment for the proposed secondary materials co-processing programme, Background Information Document, July 2006.

Shapley, Dan. 2006. Cement plants are state's top mercury pollution source. Ploughkeepsie Journal, July 16, 2006

Smailyte, G, Kurtinaitus, J, Andersen, A. 2004. Mortality and cancer incidence among Lithuanian cement producing workers. Occup. Environ. Med. 61:529-534

Yang, C., Chang, C., Tsai, S., Chuang, H., Ho, C., Wu, T., Sung, F., 2003. Preterm delivery among people living around Portland cement plants. Environmental Research. In Press.

WEB REFERENCES

W01. http://www.cementindustry.co.uk/main.asp?page=113 (29 August 2006)
W02. http://www.wbcsdcement.org/concrete_misc.asp (30 August 2006)
W03. http://www.cement.ca/cement.nsf/e/ 6338903AA45EB88F852568620008A256?OpenDocument (30 August 2006)
W04. http://www.wbcsdcement.org/about_cement.asp (30 August 2006)
W05. http://www.ecosmartconcrete.com/enviro_cement.cfm (20 September 2006)
W06. http://www.buildinggreen.com/auth/article.cfm?fileName=020201b.xml (16 August 2006)
W07. http://en.wikipedia.org/wiki/Tonne (18 August 2006)
W08. http://burningissues.org/tires.htm (04 October 2006)
W09. http://www.downwindersatrisk.org/DARNCCKCIssuesWithDioxin.htm (20 September 2006)
W10. http://www.eveningleader.co.uk/ihome2/detail.asp?storyid=34611&catid=%201&officeid=1 (March 4, 2005)
W11. http://news.bbc.co.uk/2/hi/uk_news/wales/north_east/4866282.stm (3 October 2006)
W12. http://earthguide.ucsd.edu/virtualmuseum/climatechange2/10_1.shtml (4 September 2006)
W13. http://en.wikipedia.org/wiki/Electrostatic_precipitator (4 September 2006)
W14. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?CMD=Display&DB=pubmed (19 September 2006)
W15. http://www.fwweekly.com/content.asp?article=4200 (20 September 2006)
W16. http://www.emission-watch.com/graphs.php (20 September 2006)
W17. http://www.emission-watch.com (22 September 2006)
W18. http://www.airinfonow.org/html/ed_particulate.html (22 September 2006)
W19. http://useit.umaine.edu/materials/ckd/cementkilndust.htm (22 September 2006)
W20. http://www.mindfully.org/Air/Cement-Kilns-Burning-Waste5.htm (22 September 2006)
W21. http://www.epa.gov/epaoswer/other/ckd/cement2.htm (22 September 2006)
W22. http://www.buildinggreen.com/auth/article.cfm?fileName=020201b.xml
W23. http://www.mindfully.org/Air/Cement-Kilns-Burning-Waste5.htm (22 September 2006)

NiZA
Netherlands institute for Southern Africa
www.niza.nl

Southern Africa Trust
www.southernafricatrust.org

groundWork
www.groundwork.org.za

CAE
www.cae.ukzn.za

SOMO
www.somo.nl

This project was funded by Nederlands instituut voor Zuidelijk Afrika (NiZA) and the Southern Afria Trust and facilitated by groundWork (Friends of the Earth South Africa). The Centre for Adult Education (University of KwaZulu Natal) and SOMO provided technical support and guidance.

groundWork is a non-profit environmental justice service and developmental organisation working primarily in South Africa, but increasingly in Southern Africa. groundWork seeks to improve the quality of life of vulnerable people in Southern Africa through assisting civil society to have a greater impact on environmental governance.