SECTION 11 CONCLUSIONS

The intended use of secondary materials by PPC will have many advantages to the company, South Africa and for the waste management sector in South Africa in general.

A summary some of these perceived or possible benefits include:

a) For the company:

- Substituting expensive raw materials and fuel requirements with renewable and cheaper alternative resources.

b) For South Africa:

- Extending the life of landfill sites and the associated land requirement as well as reducing the risks of pollution posed by disposal sites;
- Offering an alternative for disposal of hazardous materials to expensive processes like incineration;
- Preserving natural recourses i.e. fossil fuels and mineral deposits, and
- Reducing the risk of unwanted dumping of waste.

c) Globally:

- Contributing to a net decrease in CO_2 and other greenhouse gases emission.
- Making a positive contribution to international commitment of waste reduction including targets set in Agenda 21 of the "Earth Summit" in Rio de Janeiro (1992), the Johannesburg Declaration on Sustainable Development (2002), and the Millennium Development Goals as well as international environmental agreements, namely the Basel and Stockholm Conventions.

In our opinion, co-processing of hazardous and non-hazardous waste presents a positive alternative to landfilling and incineration, and does not present a financial disincentive to the preferred alternative of recycling. Where recycling is not an established option in terms of the South African market, cement kiln disposal is the preferred means of disposal if the components of the waste stream are suitable to the cement process. The five waste streams included in this EIA application have been chosen on this basis.

Based on the extensive research contained in this document, the advantages of the proposed project outweigh the risks. If the recommendations outlined in the next section are complied with, the risks of secondary material co-processing by PPC are sufficiently mitigated so as not to present a significant risk to the environment and community health.

The following presents a summary of a balanced and well-considered view on the respective advantages and risks of disposal to cement kiln by PPC in particular:

11.1 ADVANTAGES OF CEMENT KILN DISPOSAL BY PPC

11.1.1 Regional presence

PPC is the only cement company with operational kilns in the Western Cape and Eastern Cape, in addition to their kilns in the North West, Limpopo and Gauteng Provinces. Thus the technology development and experience gained from this project shall be replicated at all kilns, but, more importantly, such regional presence enables cement kiln disposal to become a national alternative to landfilling an incineration. One of the concerns of the introduction of new technology is the concentration of the risk onto one area or region. For example, if Hercules were the only site to receive authorisation, then concerns may be raised about the long-term transport of hazardous wastes from around the country to the one kiln, and the risks of large volumes of waste being stored and processed at one facility. PPC's proposal therefore mitigates this risk and provides a local solution to disposal of the five waste streams included in this proposal.

The concern may be raised that this may exacerbate any problems such as air emissions: whereas one kiln may be tolerated in terms of the risk of changes to air emissions, the risk of many kilns burning waste is unacceptable. This, we feel, is a National issue and not part of this provincial application.

11.1.2 Cautionary Approach

PPC will only implement (i.e. from trial burn to full operation) the secondary materials programme at one kiln at a time, thus providing as opportunity to rectify any problems during commissioning prior to beginning at another plant.

11.1.3 International trends

In the last 20 years the use of secondary materials in cement kilns has become common practice internationally due to the general benefits as listed above and the ideal chemical and physical conditions in a cement kiln for such utilization. The main development within the cement industry globally in the last century has been that of combustion of secondary materials, and has been the most researched topic by independent organisations. In some circumstances, governments in Europe and Japan have specifically requested cement companies to dispose of problematic waste streams such as that from mad-cow disease, contaminated soil and tyres.

11.1.4 Cements kilns more favourable than incinerators and landfills

Until the market responds with more economically efficient means of recovering the value from the waste streams, cement kiln disposal at least provides an efficient means of recovering 100% of the energy and mineral value of waste streams for which there are currently no other feasible recycling alternatives in South Africa. This is particularly true of hydrocarbon wastes and tyres, where the predominant quality of the waste stream is its high calorific value per ton.

A significant additional benefit is the volumes of waste which a kiln may accept. This implies that cement kilns have the potential to provide a meaningful contribution to the reduction of waste sent to landfill. Cement kiln disposal by PPC alone (by kilns servicing the Gauteng area) is, on a volumetric basis, equivalent to constructing another H:H landfill site without the capital costs and long-term environmental risks of landfill disposal.

Because they are existing facilities, there is usually less public opposition to citing of cement kilns, and the capital expenditure required is only about 10% of that needed to build a dedicated chemical incinerator.

11.1.5 Elimination and positive use of waste

Secondary materials combustion in a cement kiln is a no-waste process, as the ash is a component of the clinker. Thus the ash from the waste becomes part of an end-product: cement. Waste streams from other industries are becoming widely used as replacements for the natural raw materials, thus implying reduced impacts from mining activities.

11.1.6 Process suitability

Full combustion of secondary fuels is achieved because of the high temperatures to which wastes streams are exposed inside such kilns, high gas stream speed and the turbulent mixing with the waste and clinker materials, and the long time during which particles remain in the gas stream at these elevated temperatures. Addition of secondary materials has been show to reduce the NO_x levels in kiln emissions and monitoring of CO is a normal process control at all kilns currently. Non-volatile metals remain completely within the product and leave the kiln system fully incorporated in the mineral structure of the clinker.

Cement kilns operate on a continuous basis, therefore the temperature of the material and its distribution within the kiln are stable in time, and due to a kiln's high heat capacity even in a case of emergency stoppage, and an excess oxygen environment, the temperature does not fall very quickly and total combustion of any materials inside the kiln is guaranteed.

11.1.7 Inherent gas scrubbing ability

The alkaline environment present inside a cement kiln allows the acid components of gases to be neutralized before combustion gas is released into the atmosphere. In all kiln systems the solid material moves counter currently to the hot combustion gases. This counter current flow affects the release of pollutants, since it acts as a built-in circulating fluidised bed. Many components that result from the combustion of the fuel or from the transformation of the raw material into clinker remain in the gas phase only until they are absorbed by, or condensed on, the raw material which is flowing counter-currently. The adsorptive capacity of the material varies with its physical and chemical state. This in turn depends on its position within the kiln system. For instance material leaving the calcination stage of a kiln process has high calcium oxide content and therefore has a high absorptive capacity for acid species, such as HCl, HF and SO_2 which reduces the risk of detrimental air emissions.

The high efficiency of combustion gas purification and direct incorporation in clinker eliminates metal emissions with the exception of highly volatile mercury. Metals are condensed in the dust particles captured by the air pollution control device, returned into the process and, in the end, bonded by the clinker.

11.1.8 Product safety

Cement produced using secondary materials does not present any risk to the environment or public health, as long as the chromium content is minimised. Regarding the leaching of toxic elements from the final cement product:

1. The potential for any additional negative environmental impact due to product leaching or direct water contamination when using secondary materials is not considered significant.
2. The threat to human health due to leaching when using secondary or conventional materials is minimal and well within health standards.
3. In cases where the concentration of heavy metals exceeds the normal range found in cements made without secondary material, leaching tests should be conducted.

PPC monitors the Cr levels in cement on a regular basis although there exists no formal limit in terms of the SABS standards. The critical species is water-soluble Cr (6+), which is typically at ppm levels (less than 10ppm).

11.1.9 Greenhouse gas reduction

With the substitution of fossil fuels by (renewable) secondary fuels, the overall output of thermal CO_2 is reduced ("CO_2 neutrality"). A thermal substitution rate of 40% in a cement plant with an annual production of 1 million tons of clinker reduces the net CO_2 generation by about 100,000 tons. This comparison assumes that the renewable fuel or waste is alternatively incinerated in a dedicated incinerator. The same basic principle would be valid when the waste should decompose in a landfill site or for instance digested in a biological treatment plant. The "greenhouse" gases would also include methane, for instance. Even more important is the substitution of clinker by mineral additions as both thermal CO_2 from fossil fuels and CO_2 from the decarbonation of raw materials are reduced. Therefore, the use of secondary fuels, raw materials and mineral additions can contribute significantly to national schemes for the reduction of greenhouse gases.

11.1.10 Inherent quality assurance and process control

An important corrective mechanism regarding this proposal is the process self-regulation: PPC is required to produce clinker which conforms to defined quality requirements.

In operating a kiln, a balance is maintained between the feed rate (which is linked to kiln rotational speed), the fuel firing rate (coal, which may be partially replaced by selected secondary fuel materials), and the combustion air supply (which is drawn into the kiln by the ID (induced draught) fan). Continuous analysis (for O_2 and CO) of the kiln exit gas stream ensures that there is sufficient excess air present for complete combustion of the kiln fuel. Clinker of the correct quality will not be produced if this balance is not maintained, or if the required temperature profile over the kiln system is not maintained.

Clinker quality is assessed by means of chemical testing on an hourly basis. The continuous monitoring of kiln operation effectively results in a continuous check on clinker quality.

It is therefore in the cement company's interest to avoid unnecessary disturbances to the kiln production due to the addition of secondary materials. This is an inherent control over the relationship between the input materials and the two outputs from a kiln system, namely: the emissions leaving the kiln/preheater stack, as well as the final product (clinker). The only limitation to this self-regulatory mechanism is that there may be ingredients in the secondary materials which will not affect either kiln stability or clinker quality, but which will present a risk to environmental and community health. This pertains mainly to mercury, and is discussed in section 3.2.15.

This self-imposed level of control does not exist with incinerators. Indeed, PPC should, if the measures recommended in the following section are implemented, exceed the standards set by the Department of Environmental Affairs and Tourism for the operation of a Class 1 incinerator (in terms of Scheduled Process No. 39 of the Atmospheric Pollution Prevention Act of 1965).

11.1.11 Acceptable community health risk

Legislation exists that govern emission limits when utilizing secondary materials specifically for cement kiln in various countries. In South Africa no such legislation exists and self regulation within related acts must be established. If PPC comply with their self-imposed emissions inventory (Table 9-2), it has been indicated that the additional risk of cancer and non-cancer effects on sensitive receptors in the community is negligible.

11.1.12 Liquid effluent

The cement production process does not produce liquid effluents. All water consumed (mainly for gas cooling purposes) is released to the atmosphere as water vapour. This situation will not change as a result of the introduction of secondary materials.

11.2 RISKS OF CEMENT KILN DISPOSAL BY PPC

11.2.1 Air emissions

The principal concern when using cement kilns for co-processing of waste is the possibility of additional air emissions, in particular those of dioxins and furans and volatile and semi-volatile metals such as mercury, cadmium, lead and thallium. Apart from the engineering challenges in modifications to operations to allow the use of secondary material, extensive studies and research has been done in assessing the pollution risks posed.

Particulate and gaseous emissions to the atmosphere i.e. dust, SO_2, NO_x, VOC in raw material, and CO_2, comprise the major environmental impacts in the manufacture of clinker and cement. Gaseous emissions – except for NO_x – are mainly caused by the chemical characteristics of the raw materials, and not of the fuels. Other gaseous emissions such as hydrochloric acid or hydrofluoric acid are nearly completely captured by the inherent and efficient alkaline scrubbing effect of the cement kiln system, and are far below the regulatory limits.

It is now, however, generally accepted by cement kiln operators and first world country environmental legislators that it is ecologically safe to use secondary materials in cement kilns under certain conditions, which have been stipulated within the recommendations section of this report. Such measures would include limiting the input quantities of sulphur, chlorine and volatile and semi-volatile metals. As it is the only metal which can be emitted with the clean gas in gaseous form, the input of mercury with raw materials and fuels has to be carefully controlled. Although the carbon monoxide measured in the stack gas is an indicator of incomplete combustion of conventional or secondary fuels, it will be influenced by some of the VOC converted to CO. Hydrocarbon contents in the stack of cement kiln systems are essentially determined by the content of organic matter in the raw materials. This is an important point to consider when applying secondary materials in that the organics introduced by secondary materials, as in the case of organics introduced with coal, are combusted entirely within the kiln if introduced to the kiln where the temperature is sufficiently high (i.e. 1,450 °C).

Certain types of cement kiln configurations are not ideal for the use of secondary materials. For long dry kilns, or for kilns with preheater stages and no conditioning tower, the chloride and carbon contents of materials introduced as secondary raw materials (i.e. at the kiln back end) have to be limited and dioxin emission levels established during trial burns. Chloride compounds are seen to have a high evaporation factor. At approximately 800°C these compounds are melted and at 1,200-1,300°C they are almost entirely evaporated. Similarly, volatile organic compounds will be volatilised in the early stages of heating in a long-dry or preheater kiln. Together, the chlorides and VOC's present pre-cursors for dioxin formation, and their input into the back-end or preheater section of the kiln should be limited. A suitable limit for total Cl would be 310 mg total input (fuel and raw materials) per kg clinker produced, with the majority being fed as fuels. The effect of this on dioxin/furan formation would need to be verified during the proposed trial burns.

It is our opinion that this risk does not exist for secondary material fuels introduced at the flame-side of the kiln (the front end).

Similarly, inorganic and organic sulphur compounds introduced with the fuels will be subjected to the same internal cycle consisting of thermal decomposition, oxidation to SO_2 and reaction with alkalis or with calcium oxide. With this closed internal cycle, all the sulphur which is introduced via fuels or via raw material sulphates will leave the kiln chemically incorporated in the clinker, and will not give rise to gaseous SO_2 emissions. On the other hand, sulphur entering the kiln via raw materials will leave as SO_2 in the stack if they are present as pyrites. These volatilize at temperatures below 600°C. Sulphides (and also organic sulphur compounds) in raw materials, however, are decomposed and oxidized at moderate temperatures of 400 to 600°C to produce SO_2 when the raw materials are heated by the exhaust gases. At these temperatures, there is insufficient calcium oxide available to react with the SO_2.

Therefore, in a dry preheater kiln, about 30% of the total sulphide input may leave the preheater section as gaseous SO_2. During direct operation – i.e. with the raw mill off – most SO_2 is emitted to the atmosphere. During compound operation – i.e. with the raw mill on-line – typically between above 90% of the remaining SO_2 is additionally adsorbed on to the freshly ground raw meal particles in the raw mill. In long dry kilns, the chemical absorption capacity for SO_2 is generally lower due to the reduced contact between kiln exhaust gas and raw materials. In these kiln systems, all kinds of sulphur input may partially contribute to SO_2 emissions, and the general emission level may be higher than in preheater kilns.

Gaseous emissions such as SO_2, VOC, CO, dioxins and furans, are to a large extent determined by the chemical characteristics of the raw materials used, and not by the fuel composition. Emissions are lowest with raw materials which are low in volatile components and injection of materials containing significant quantities of volatile components (Cl, S and carbon) should occur at the flame-side of the kiln.

The results of an air dispersion model run on Dwaalboom, using the self-imposed emissions inventory show negligible effects on community health. PPC's commitment is to maintain current levels of dust (according to the APPA permit), CO and NO_x emissions and EU limits for the other parameters. It is true that the Jupiter trials results (table 10.6) show results for dioxin equivalents as being 1.4 ng/Nm^3, as compared to that of 0.1 ng/Nm^3 (the EU limit), although the data also confirms a destruction rate meeting USEPA standards. On the other hand, the EU limits for HF limits are met for SPL processing (which is a waste high in F content). As to whether these EC emissions are achievable at Dwaalboom, Table 5-3 shows that that compliance with the EC limits is achievable for the measured parameters, as long as input controls are maintained. It is, however acknowledged that no current emissions data exists for TOC, metals and dioxins. Dioxins and volatile metals will be managed by controlling input quantities through the sampling and analysis procedure (see Section 4.1), and TOC is expected to be controlled through the introduction of most of the organics at the same time to the kiln, where a destruction rate efficiency of 99.9999% is expected to be achieved.

Latest technology monitors are being installed at all facilities to monitor critical emissions on-line, in addition to the current dust monitors. For dioxin emissions, a sufficiently thorough monitoring campaign has been designed. Furthermore, independent auditing and reporting to authorities has been agreed to by PPC to ensure transparency regarding air emissions in particular.

11.2.2 Process Risks

Cement kilns have been primarily designed to produce clinker, and modifications to operating equipment, procedures, monitoring and training are inevitable because of the unique chemistry and reaction mechanisms involved with incineration of waste. PPC have commenced with a HAZOP study to determine the process risks associated with such changes, and this study needs to be completed prior to the commencement of any trial burns. Emergencies such as fire, explosions or spillage/leakage are extremely rare in the cement industry. Potential consequences for the environment are minimised by adequate prevention and protection measures such as fire and explosion proof design of machinery and emergency response schemes.

A summary of the production and environmental risks of various input components or properties is outlined in the table below.

Table 11-1: Production and Environmental Risks as a result of various input components or properties

Constituent or Property	Production Risk	Environmental Risk
Chlorides	Build-up in kiln system resulting in process blockages	HCl or dioxin emissions if introduced in raw material in excessive quantities, and in the presence of VOC's
Fluorides	Kiln instability due to lowering temp required to achieve sintering	HF emissions
Sulphur in fuels	Build-up in kiln system resulting in process blockages	SO_2 emissions
Non-volatile metals	Quality of clinker	None (absorbed in clinker)
Calorific Value of fuel	Too low – reduction of flame intensity Too high – overheating of kiln resulting in gas change at back-end	CO emissions (but fully oxidised in riser) None
Moisture	Weak flame and gas flow changes	None (CO fully oxidised in riser)
Fuel particle size	Slow rate of combustion & incomplete combustion	CO emissions

11.2.3 Risks of hazardous waste handling, storage and transport

Hazardous waste handling in itself poses many challenges and is subjected to various legislative requirements. Spills and accidents may occur wherein large quantities (up to 30,000 l per load) may be released to the soil and surface water bodies. Although the nature of these risks are the same as the risks of transportation of these waste streams to a hazardous landfill site, the risk may be amplified due to the longer transportation distances required to bring these wastes to the kiln. The nature of the 5 waste streams considered by PPC in this application do, to a degree, limit the impacts from such an incident. Paper, sludge pellets, plastic and tyre waste are considerably inert and may only present a litter/physical and visual impact on any sensitive receiving environment before being cleaned up. Pulp and paper sludges (with a high pH and corrosive in nature) and hydrocarbons (with toxic components, i.e. metals and possible PCB's, high chemical oxygen demand and flammability) present a different risk and therefore require specific emergency response plans. These will be compiled in accordance with the relevant SANS codes under the National Road Traffic Act (i.e. SANS 10232-1 to 3). Any contaminated soil arising from any clean-up exercises could be disposed of to the same kiln for which the waste load was originally intended (subject, of course, to the necessary approvals).

11.2.4 Variations in compositions of waste streams

The variety of possible secondary materials that could be used is vast and the composition could vary infinitely making generalization of results difficult. All additions of secondary materials to the cement kiln operation result in more complexity of process control, thereby increasing the chances of upset conditions. This will be managed partially by the cautious approach listed above, but also by the comprehensive sampling and analysis programme (prior to waste acceptance) listed in Section 4.1 of this report.

11.2.5 Absence of empiric models

No readily-available mathematical predictions of the fate of elements in a cement kiln exist. Most European countries use concentration limits for the pollutants in the exhaust gas from cement plants to limit the emission impact to an acceptable degree but input limits ensure operation within these limits must be obtained empirically.

11.2.6 Absence of previous experience besides SPL

No actual benchmark or best practice information is available in South Africa for continuous use of secondary materials, apart from the SPL used by PPC. On the other hand, PPC has been investigating secondary materials application for more than a decade. Various trial burns, DRE tests, risk analyses, and investigations by external consultants have been completed. PPC also started utilizing spent pot liners (SPL) as a secondary material on a small scale in 2001. Valuable information and data has been acquired concerning the handling, use and monitoring of secondary materials. The results from these studies mostly confirm the international findings and suitability of the use of certain secondary materials and that cement kilns can achieve the same destruction rates as purpose-built incinerators.