# Environmental Benefits of Using Spent Pot Lining (SPL) in Cement Production

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**Abstract**

Spent pot lining (SPL) is a toxic waste material produced during the pot replacement process in the aluminium industry. Recently, SPL has been diverted from landfills to cement manufacturers as a raw material replacement. This paper presents a comprehensive environmental assessment of a case study in the United Arab Emirates (UAE), where SPL from Emirates Global Aluminium (EGA) was used as a feedstock at a cement plant in Ras Al Khaimah, UAE. Three areas of environmental concern were studied: fuel savings and $CO_2$ reductions, changes in $NO_x$ emissions, and raw material repurposing and toxic substance destruction. Using 0.6 % SPL in feedstock was estimated to reduce coal consumption by 3.5 %, $CO_2$ emissions by 0.65 %, and $NO_x$ emissions by 3.8 %. These changes are primarily attributed to the fluoride content in SPL creating fluoride fluxing effects that reduce the high temperature requirements of the cement kiln. Lower kiln temperatures lead to lower coal consumption and thermal $NO_x$ generation. Toxic materials such as cyanides and fluorides were destroyed or fixed during the cement production process to below detection limits. However, SPL addition to cement production is limited by maximum alkali content standards of cement products. The use of SPL in cement production is shown to yield significant environmental benefits in terms of reducing emissions and coal consumption and destroying toxic substances. This initiative bolsters the concept of a circular economy in which different industries collaborate to improve environmental sustainability.

## 1. Introduction

Aluminium smelting is often viewed as significantly detrimental to the environment [1]. The primary reason for this perspective is the large amount of electricity that is required by the electrolytic process to produce aluminium metal and the oxidation of the carbon anode, both of which would release substantial amount of carbon dioxide ($CO_2$) if the electricity is generated through fossil fuel combustion. In addition, the process also produces significant quantities of toxic spent pot lining (SPL) materials as a by-product [1]. Consequently, the motivation for this study was to understand the viability of repurposing SPL waste material while deriving environmental and sustainability benefits.

In aluminium production, the cathode and refractory lining of the pot is exhausted after it has spent 4 – 5 years producing aluminium in the pot line. The pot is then taken out of service and the lining material removed becomes spent pot lining. The SPL contains toxic materials such as cyanides and fluorides. As one of the primary aluminium producers in the world, Emirates Global

Aluminium (EGA) produces approximately 33 000 tonnes of SPL per year. Since 2009, EGA has been diverting SPL from landfills to cement manufacturers as a raw material replacement. The main reason for the diversion is to reduce the ecological footprint of aluminium production. For the cement plant accepting SPL, traditional feedstock flow can be decreased because a substantial amount of metal oxides in SPL are the same as those in standard cement raw materials [2 – 5].

There are three major stages in cement production: 1) physical processing, 2) clinker production, and 3) cement grinding. In the physical processing step, limestone and supplementary feedstock such as sand, shale, iron ore, SPL, and others are extracted and milled. The feedstock materials are combined in specific proportions to produce a mixture with tightly controlled compositions called raw meal. The raw meal enters the clinker production process and undergoes successive application of heat in various stages to produce clinker nodules: pre-heater cyclones, the calciner, and the rotary kiln. Clinker quality is primarily determined by the free lime (CaO) content, which is a main determinant of the resulting concrete strength. In addition, clinker quality is determined by other parameters such as total alkali and density. In the last step, clinker nodules are ground with gypsum to produce cement [6].

SPL can play several roles in the cement manufacturing process. In a cement plant, coal is the traditional fuel used in the kiln and calciner, and the carbon in SPL can act as an alternative fuel source. Silicon, aluminium, iron, calcium, and magnesium oxides in SPL act to replace traditional cement raw materials and are incorporated into the final clinker product. [2] Fluorides in the SPL can act as fluxing agents which may lower the required reaction temperature and produce catalytic and mineralization effects [7 – 8]. The lowered reaction temperature can reduce the amount of thermal nitrogen oxides ($NO_x$) produced and the amount of fuel coal required. Since the combustion of coal releases significant quantities of $CO_2$ and $NO_x$, a reduction in coal usage can lower the emissions of both $CO_2$ and $NO_x$. Cyanide-containing compounds from the SPL can potentially serve as a scrubber for $NO_x$, leading to lower $NO_x$ emissions [9].

The primary environmental benefit of using SPL in cement production is the transformation of "unwanted" waste SPL into valuable feedstock for industries such as cement manufacturing, iron and steel production, and brick manufacturing, promoting cross-industrial cooperation and a circular economy. Secondly, there may be reductions in the environmental footprint with respect to $CO_2$ and $NO_x$ and due to the repurposing of SPL materials. This study seeks to assess the environmental effects of SPL utilization in cement production through estimating reductions in $NO_x$ emissions, fuel consumption and carbon emissions, and waste and/or toxic materials.

## 2. Methods

To assess the environmental benefits of SPL utilization in cement manufacturing, a cement plant located in Ras Al Khaimah, UAE was used as a case study. This cement production facility produces around 8000 – 8500 tonnes of clinker ($t_{clinker}$) per day (347 $t_{clinker}$/h), with an annual capacity of around 2.8 million $t_{clinker}$, and has been using 0.6 % SPL as part of its raw meal for the past few years. Both laboratory experiments and computational modeling were used to estimate the effects of SPL addition.

Burnability tests were performed at the analytical laboratory in this cement plant to quantify the effects of SPL on clinker quality, cement manufacturing process conditions, and toxic materials destruction. This test is typically carried out at cement plants before introducing any new Alternative Raw Material (ARM) to understand the impact of ARM on clinker quantity. The burnability tests were performed by forming nodules from the raw meal and drying them in an oven at 105 °C. Subsequently, the dried nodules were fired in a muffler furnace at a constant temperature for 30 min. The parameters varied were the quantity of SPL addition (0, 0.5, 0.75, 1.0, 1.5, 2 %), and the muffler furnace firing temperature (1250, 1300, 1350, 1400, 1450 °C). In

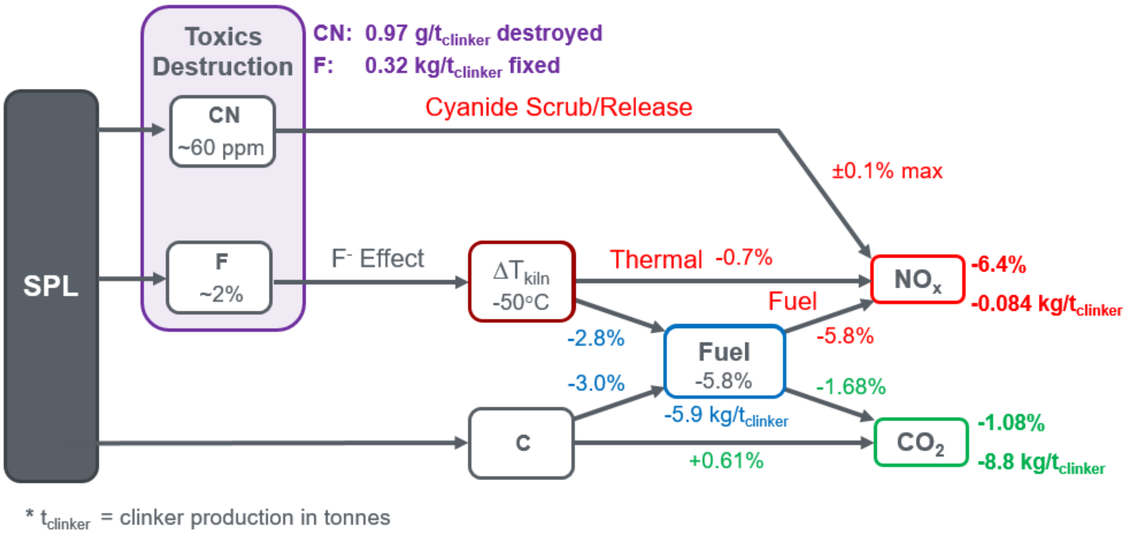


**Figure 10. Summary of the environmental impact of SPL addition on cement production within the cement facility. All values are on a per % SPL in raw meal basis.**

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