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# Destruction of concentrated chlorofluorocarbons in India demonstrates an effective option to simultaneously curb climate change and ozone depletion

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ABSTRACT

The Montreal Protocol aims to protect the stratospheric ozone layer by phasing out production of substances that contribute to ozone depletion, currently covering over 200 individual substances. As most of these compounds are synthetic greenhouse gases, there is an opportunity to curb both ozone depletion and climate change simultaneously by requiring Parties of both the Montreal and the Kyoto Protocol to destroy their existing stocks of concentrated chlorofluorocarbons (CFCs). Many emerging countries still possess stocks which need to be destroyed in an environmentally sound manner but costs may be prohibitive.

The UNEP Technology and Economic Assessment Panel identified in 2002 eleven destruction technologies which meet the criteria for environmentally sound destruction of chlorofluorocarbons. Cement kilns were among these, but no study has been reported in scientific literature assessing its destruction performance under real developing country conditions up to now. In contrast to incinerators and other treatment techniques, high temperature cement kilns are already in place in virtually every country and can, if found technical feasible, be retrofitted and adapted cost-efficiently to destroy chemicals like CFCs. India has the second largest cement industry in the world and several hazardous waste categories have been tested successfully in recent years.

The objective of this study was to carry out the first full scale demonstration involving high feeding rates of concentrated CFC-gases in a local cement kiln and to assess its feasibility and destruction performance. The test in Madhya Pradesh demonstrated that the kiln was able to destroy several concentrated CFC-gases effectively in an irreversible and environmental sound manner without causing increased releases of HCl, HF or PCDD/PCDF.

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The destruction and removal efficiency was >99.9999% and the overall environmental performance in compliance with Indian regulation and international best practice.

The test also revealed that cement kilns have a much higher disposal capacity than previously anticipated and that such undertaking can contribute significantly to reduce the release of both ODS and greenhouse gases; the destruction of 16.3 tonnes of CFCs done in this demonstration is equivalent to saving the release of 131,265 tonnes of $CO_2$ to the atmosphere.



## 1. Introduction

Chlorofluorocarbons (CFCs) and halons (brominated fluorocarbons/CFCs) are potent ozone depleting substances (ODSs) and synthetic greenhouse gases (GHGs). All ozone depleting substances contain either chlorine or bromine; substances containing only fluorine do not harm the ozone layer but may still be a GHG. The interim replacements for CFCs are hydrochlorofluorocarbons (HCFCs), which deplete stratospheric ozone, but to a lesser extent than concentrated CFCs. Ultimately, hydrofluorocarbons (HFCs) will replace HCFCs.

The wide use of these chemicals has caused severe damage to the ozone layer and contributed significantly to the global warming. The global warming potential (GWP) refers to the amount of global warming caused by a substance and is the ratio of the warming caused by a substance to the warming caused by a similar mass of carbon dioxide; thus, the GWP of $CO_2$ is defined to be 1. The GWP of CFC-11 is 4750, CFC-12 10,890 and CFC-113 6130 over a time horizon of 100 years (WMO, 2010).

The Montreal Protocol on substances that deplete the ozone layer entered into force in 1989 and called for a phase out of all concentrated CFCs by 2010. There are however no provisions in the Montreal or in Kyoto Protocol (the United Nations Framework Convention on Climate Change, UNFCCC) to report on or to destroy existing stockpiles of concentrated CFCs, and quantities of current stockpiles are uncertain.

Many emerging countries, such as India, still possess stocks of concentrated CFCs which need to be destroyed in an environmentally sound manner but costs are prohibitive. Current accepted treatment technologies can be classified into two methodologies: destruction and conversion. In conversion processes, they are transformed into environmentally benign and in some cases chemicals of economic value, while CFCs and halons are converted into hydrogen halides and $CO_2$ in destruction processes (Hai et al., 2006). The UNEP Technology and Economic Assessment Panel (TEAP) task force on destruction technologies applied screening criteria to 45 identified technologies, where eleven met the qualification criteria for destruction of concentrated sources, i.e. CFCs and HCFCs (UNEP, 2002).

Despite the fact that cement kilns were among the methods recommended by UNEP TEAP in 2002, no study to assess their feasibility and destruction performance under real developing country conditions has been reported in the scientific literature up to now. The UNEP TEAP report mentions only one cement kiln test, conducted in Japan in 1997.

Cement kilns are currently used in many countries to recover energy and recycle materials in wastes, i.e. by substituting fossil fuels and virgin raw materials, to increase waste treatment capacity and subsequently reduce $CO_2$ emission from cement production. High temperature cement kilns have shown to be feasible to destroy many types of organic hazardous chemicals, and can constitute a sound and cost-efficient treatment option, especially for developing countries without dedicated technologies (Karstensen et al., 2006, 2010). The most modern and energy efficient and least polluting kilns, i.e. BAT/BEP, are today erected in emerging countries where cement and concrete are needed for infrastructure development.

India has the second largest cement industry in the world, with 181 kilns, and has recently been exploring the possibility to increase waste treatment capacity through co-processing of wastes in the cement industry (Kamyotra et al., 2013a) and several hazardous waste categories have been tested successfully (Kamyotra et al., 2013b).

The objective of this study was to carry out the first demonstration with high feeding rates of several concentrated CFC-gases in a local cement kiln, to assess its feasibility and destruction performance under real developing country conditions and to evaluate its effectiveness in curbing climate change and ozone depletion simultaneously.

## 2. Materials and methods

Co-processing of wastes in cement kilns is first of all about recovery of energy and recycling of materials in the waste, i.e. substitution of fossil fuel and virgin raw materials. However, given a lack of available treatment options and urgent needs, a feasible cement kiln can be used for treatment of organic hazardous constituents if done under strict control and Government guidance (Stockholm Convention, 2008; Karstensen, 2011).

### 2.1. CFCs destroyed

The CFCs destroyed in this investigation had been stored by Navin Fluorine in Mumbai for more than a decade waiting for a cost-efficient treatment option to emerge. The chemical and physical characteristics of the three CFC-gases are given in Table 1 (WMO, 2010).

### 2.2. Local cement plant in Madhya Pradesh

A technical feasibility study was conducted prior to the selection of the cement plant; ACC Keymore plant in the state