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Potential impacts of emissions from amine-based CO_2 capture plants on the reactivity of surrounding air

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1. Introduction

Atmospheric emissions from amine-based post combustion capture (PCC) systems are expected to be significantly different from those of conventional power plants. However, these emissions are not yet well characterised and a detailed understanding of their atmospheric chemical transformation is still required.
Currently, it is not possible to describe the entire atmospheric life cycle or fate of amines used in PCC. Gaseous amines and some of their degradation products have the potential to undergo atmospheric oxidation reactions with OH, NO_x, O_3 and HNO_3. The chemical reactions between amines and hydroxyl radical (OH) are considered to be fast of the order of few hours compared to around 60 days for ammonia. Also, chemical reactions between volatile organic carbons, such as alkanes, are much slower with OH, compared to that of amines. In addition, the photooxidation of selected amines by various nitrosating compounds can produce N-nitroso compounds which are known to be carcinogenic.

An empirical chemical reaction scheme based on limited smog chamber experiments for selected ambient conditions was developed to describe the photooxidation processes of amines in the atmosphere. This scheme can be embedded into an air quality model to simulate the resultant air pollutants profiles over a selected region.

Emissions from a typical PCC plant will be used as input for a selected air quality model that includes an empirical maine chemistry to predict pollutant concentration profiles over a selected modelling domain where a PCC plant may be deployed. An updated version of The CSIRO Air Pollution Model (TAPM) is used to calculate the transport and turbulent dispersion of gases/pollutants released to the atmosphere and to the concentrations of pollutants in the region around a selected source. This information is needed by the industry and air quality regulators for the protection of human health and the environment from potential adverse impacts of emissions. This technique will provide the appropriate tools needed to carry out future air quality assessment and risks evaluation.

2. Method Description

The absorption of CO2 in aqueous amine solutions is one of the most attractive techniques for carbon capture. Amines are volatile organic compounds with strong acid-neutralising capacity with relatively little is known about their atmospheric chemistry, reactivity and kinetic properties. Like conventional power generation utilities, atmospheric emissions from power plants equipped with amine- based PCC systems will be subject to public scrutiny and government regulation. In a conventional power plant, stack emissions of environmental concern (apart from CO_2) generally include NO_x, SO_2, particulate matter, and trace quantities of various other compounds, depending on the type of fuel. Emissions from an amine PCC plant, on the other hand, are likely to be substantially different. Along with the obvious reduction in CO_2, the concentrations of acid gases such as NO_x and SO_2 will be lower because they are removed by reacting with the basic amine solvent. Solid particulate matter (e.g. fly ash), too, is likely to be reduced since it will be physically washed out of the gas stream to some extent as it passes through the capture plant (although solid particulate matter emissions from gas-fired plants are generally very low). Countering this, however, is that some other species not normally associated with power station emissions will be produced. For instance, despite the relatively low volatility of alkanolamines, it is inevitable that some of the amine will escape from the plant.

It has been estimated that the flue gas from a proposed PCC plant could contain a single-figure ppm levels of amines that can be emitted to the atmosphere. Other compounds may be formed by thermal degradation of the amines or by chemical transformations that occur within the absorber and stripper columns and these, too, may escape from the plant. Complicating the issue further is that numerous amine compounds can be used for CO_2 capture, including proprietary blends with unknown compositions. Additives such as corrosion inhibitors, foam suppressants and pH buffers may also affect emissions. Clearly, characterising the full scope of the emissions from a large scale amine capture plant will be a considerable analytical challenge.

Amines are expected to play a major role in the formation of secondary pollutants in the atmosphere. For example, it is likely that they will influence the formation of ozone, ammonia and secondary aerosols. In the case of the latter, amines may be an important precursor of organic salts and organic nitrogen in the atmosphere, thus representing a substantial fraction of the organic aerosols. The understanding of the organic nitrogen chemistry and the formation of aerosols is currently still developing. Organic nitrogen compounds might influence atmospheric chemistry, air quality and nutrient budgets of ecosystems. The importance of the deposition of these aerosols on surface waters and soils needs to be elucidated.

The atmospheric degradation pathways for the MEA solvent were investigated using smog chamber experiments. These studies identified various oxidation products such as NH_3, aldehydes, aerosols and other amine-N products yet to be determined. An empirical model to predict the concentrations of expected pollutants has been developed and embedded into an air quality model to predict the spatial and temporal distribution of these pollutants over a given airshed.

The dispersion of these pollutants involves several different mechanisms: (i) advection of pollutants by air movements, (ii) mixing of pollutants by atmospheric turbulence, and (iii) molecular-scale mass diffusion due to concentration gradients. In addition, the location of the sources, the nature of the terrain downwind from the sources, and the physical and chemical nature of the pollutants all affect the concentrations downwind from the source(s).