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# Environmental impacts of amines and their degradation products: Current status and knowledge gaps

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## 1. Introduction

Many post combustion CO<sub>2</sub> capture (PCCC) plants are designed to operate using amine-based solvents to remove CO<sub>2</sub> from gaseous effluents. Although monoethanolamine (MEA) is the most commonly used solvent, an increasing range of other amines are being studied for potential use. Amines undergo degradation within the process, forming a variety of degradation products. Both amines and degradation products can be released into the environment in emissions from the plant, even if efforts are made to clean the emissions (e.g. water wash systems). In the environment, amines and process degradation products are subject to further degradation processes. The first and possibly most important of these degradation processes will occur in the atmosphere. Many amine solvents are considered to pose a relatively low environmental risk. However, a number of the suggested degradation products belong to classes of chemicals of risk, especially nitrosamines and nitramines with established human health and environmental impacts. There is concern at this stage in the development of PCCC technology that the release of such compounds into the environment may lead to human exposure and associated health effects. This presentation summarises some of the most important risks involved with PCCC, and identifies existing knowledge gaps.

## 2. Current status

To date, most theoretical and experimental work has focused on MEA, although an increasing number of studies are investigating other amine solvent systems. Computational chemistry and modelling approaches have been used to predict the most likely degradation products for MEA and other amine solvents in the process. These data indicate a wide range of possible degradation products, including ammonia, nitrosamines, nitramines, alkylamines, aldehydes and ketones (1). Results indicate that those compounds of most concern (e.g. nitrosamines and nitramines) would be formed in very small amounts. Nitrosamines have subsequently been detected in measurement campaigns, but currently not nitramines. It is estimated that ammonia would be the main degradation product for most amines. Current work is underway to determine the chemical composition of the emissions experimentally.

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Following emission from the plant, atmospheric processes such as dispersion, transport, deposition and degradation to form secondary products are expected to influence the fate of the compounds. Recently a number of studies have attempted to address some of these issues using theoretical modelling approaches. These have been used to predict deposition and expected dispersion and transport routes away from the source at the local and regional scales for facilities located at Mongstad, Norway (2). A combination of modelling approaches and experimental work has been used to study atmospheric degradation on amines and their degradation products (3).

Human health hazards are associated with several of the suggested degradation products, but data for some products are not available. Potential long-term effects associated with mutagenicity, genotoxicity/carcinogenicity and reproduction effects are documented for nitrosamines, volatile aldehydes and alkylamines. It is suggested that nitrosamines may contribute to the health risk of the population, although their emission concentration is small (1). However, the real risks cannot be estimated until the fate of these compounds has been determined.

The ambiguity surrounding degradation product composition and concentration means most terrestrial and aquatic environment studies have focused on amines only. However, a recent study assessed the biodegradability and ecotoxicity of MEA degradation products (1). All compounds except one appeared to be biodegradable (30-100%), whilst ecotoxicity varied significantly. The combination of expected low emission, water-solubility (low bioaccumulation potentials), biodegradability and low to moderate acute ecotoxicity for most of the post combustion degradation products, indicate that the environmental risks and indirect health risks from drinking water and crop contamination should be moderate or low (1). However, some degradation products may persist in the environment due to low biodegradability, posing a possible risk if accumulated in aquatic systems.

### 3. Knowledge gaps

A number of significant knowledge gaps must still be addressed to identify risks associated with amine-based PCCC technology. The composition and concentration of amines and degradation products present in the emissions from a PCCC plant represent a major knowledge gap. The emissions for MEA are yet to be fully characterised in terms of chemical composition, chemical concentration and how these parameters may alter over the operating time of the plant. Furthermore, individual assessment will also be required for other amine solvents and solvent mixtures.

Another knowledge gap concerns the environmental fate of amines and their degradation products in atmospheric, terrestrial and aquatic systems. Atmospheric processes of emissions from PCCC plants are poorly understood, and thus the deposition of amines and degradation products to soil and aquatic environments is difficult to predict. Until reliable emissions data and atmospheric dispersion and process models are generated, environmental fate and effects studies will be restricted to estimates with very high uncertainty. The assessment of amines and degradation products in complex environmental samples, such as water and soil, is complicated by a lack of suitable extraction and analytical chemical methods.

The health effects of classes of compounds are relatively well understood from previous studies. However, specific studies on long-term effects such as carcinogenicity and impaired reproduction have not been completed for any of the nitrosamine and nitramine compounds identified as degradation products in plant emissions.

Finally, nitrate may be formed by biological oxidation of ammonia (nitrification), and high input of ammonia may result in increased fertilization (and ultimately eutrophication) effects. To date little work has been conducted to investigate and evaluate this issue.

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