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Predicting amine mist formation based on aerosol number concentration and size measurements in flue gas

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Abstract

Amine based solvent used for CO_2 capture can be lost during the process due to: degradation, vaporization, mechanical losses and aerosol (mist) formation. Only recently, studies have appeared pointing out that aerosols can dominate the total amine emission at pilot plant scale behind coal fired power plants. Future full scale amine scrubber installations will be imposed emission limit values (ELV) for a number of components including NH_3 and the amine itself. Most likely these ELV will be expressed as maximum concentrations tolerated in the CO_2 poor flue gas leaving the stack so it is important to prevent or cure amine aerosol emission. The study presents a novel combination of two existing measurement techniques, that measure: (i) amine emissions from the top of the absorber using FTIR and (ii) PSD of the incoming flue gas using the ELPI$^+$. The study is the first to show how combining these two measurement techniques allows to predict the presence or absence of mist formation. This hypothesis is based on information obtained during several measurement campaigns on different pilot plants.

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Keywords: amine emission, aerosol, mist, Fourier Transformed Infra Red (FTIR), Electrical Low Pressure Impactor (ELPI)

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1. Introduction

Post combustion carbon capture (PCCC) is based on the removal of CO_2 after the combustion of a fossil fuel. Reactive absorption is one of the most important techniques for the removal of CO_2 from flue gas. This reactive absorption process makes use of the reversible nature of the chemical reaction of an aqueous alkaline solvent (usually an amine) with an acid gas (CO_2). The amine based solvent can be lost during the process due to: degradation, vaporization, mechanical losses and aerosol (mist) formation. Studies on emission processes such as vaporization and mist formation exist at laboratory conditions [1, 2, 3]. Only recently, studies have appeared pointing out that aerosols can dominate the total amine emission at pilot plant scale [4, 5, 6, 7 , 8, 9, 10, 11, 12].

The origin and driving factors of the NH_3 and monoethanolamine (MEA) emissions including mist formation phenomena as measured at different pilot plants using a Fourier Transformed Infra Red (FTIR) analyser were recently published [10]. Mist precursors can be ultrafine liquid or solid particles of sulphuric acid, salts or any form of particulate matter in the flue gas entering the absorber from for example a coal fired power plant [4, 11]. Submicron (< 1 μm) particulate matter or H_2SO_4 aerosols may serve as nuclei for the formation of amine aerosols [4]. Particles in the form of soot (10^6 number of particles per cm^3) can cause MEA emissions in the order of 200 mg Nm^{-3} [11]. H_2SO_4 aerosols with a particle number concentration in the order of 10^8 per cm^3 can lead to MEA emissions in the range of 600-1100 mg Nm^{-3}.

Future full scale amine scrubber installations will be imposed emission limit values (ELV) for a number of components including NH_3 and the amine itself. Most likely these ELV will be expressed as maximum concentrations tolerated in the CO_2 poor flue gas leaving the stack. The exact value of the ELV will depend on the local authorities but it is clear that the high amine concentrations measured during mist formation phenomena will not be tolerated. Therefore, countermeasures need to be implemented. For the design of different countermeasures types and location (upstream or downstream the amine plant), it is crucial to have an idea of the aerosol size distribution and number concentration entering or leaving the absorber.

Recently, a relation between measurements of the aerosol sizes and numbers entering and leaving a MEA mini-pilot absorber was published [13]. These data can serve future installations when designing aerosol emission countermeasures. The generated H_2SO_4 aerosols sent into the mini-pilot absorber are observed to be extremely small (i.e. <0.2 μm) with number concentrations exceeding 1E8 cm^{-3}. The aerosols grow in size as they travel through the mini-pilot absorber through the taking up of water and amine to sizes close to but staying below 1 μm. However, despite the fact that most of the aerosols (expressed in number concentrations) are well below 1 μm, most of the water (and thus amine) is found in the aerosol sizes between 0.5 and 2 μm. Therefore, if one aims at designing efficient countermeasures, eliminating this size fraction is crucial.

The work presented here builds further on the lessons learned in previous work and presents Particle Size Distributions (PSD) and corresponding total number concentrations measured upstream of different carbon capture pilot installations around the world. The combination of amine measurements using FTIR behind the absorber and linking it to PSD measurements in front of the absorber is novel. The objective of the paper is apart from presenting these novel data, the formulation of a hypothesis that allows to predict mist formation based on the PSD of the incoming flue gas. It is important to note that throughout this work, MEA was used as a solvent.