ABSTRACT – 18th World Congress of CIGR – Beijing – September 2014

Modelling of a chemical air scrubber for the removal of gaseous emissions from pig housing facilities

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Type of Presentation: ORAL

Abstract: Since 2004, newly built pig housing facilities in Flanders are legally required to implement low emission techniques with regard to ammonia. This can be achieved e.g. by applying air scrubbers that remove ammonia from the outgoing ventilation air through absorption in water, followed by chemical and/or biological conversions. Despite the widespread use of such systems, measurements at animal housing facilities show that the required removal efficiency is not always reached. Besides ammonia removal, increasing attention is paid to odorous emissions due to suburbanisation. However, air scrubber designs are not yet fully adapted to this trend. Furthermore, there is a growing international concern for the livestock related greenhouse gasses methane and nitrous oxide. To fully exploit the potential of air scrubbers, further process optimization in terms of design and control is required. This goal can be achieved through a combination of modelling and simulation with full-scale monitoring campaigns.

In this study, a mechanistic (physical-based) model for a counter-current chemical air scrubber was set up, including mass balances for ammonia, hydrogen sulphide, nitrous oxide, methane and water, besides a heat balance. A simulation study was conducted for an air scrubber installed at a pig housing facility for 1250 fattening pigs, assuming an emission factor of 2.8 kg $NH_3.pig^{-1}.h^{-1}$ and an average ventilation rate of 35 $m^3.pig^{-1}.h^{-1}$. An ammonium removal efficiency of 70% was obtained, while the ammonia gas profile through the air scrubber showed an exponentially decreasing trend. The removal efficiency of hydrogen sulphide, methane and nitrous oxide was very low (less than 1%) due to low water solubility. The temperature of the exhaust air decreased until the outgoing air reached the wet bulb temperature. Evaporation of the water phase took place, leading to an increased relative humidity (typically from 65% to 100%).

The influence of design parameters, disturbance variables and control handles on the ammonia removal efficiency and the water evaporation rate was investigated. An increased incoming ammonia concentration, for a constant ventilation rate, resulted in a decreasing ammonia removal efficiency. Increasing the ventilation rate, for a constant emission factor, led to a decrease in the ammonia removal efficiency, which was caused by the reduced contact time in the scrubber rather than by the decreased (due to dilution) incoming ammonium concentration. The removal efficiency is negatively

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affected by an increased temperature, as the latter significantly affects the gas-liquid equilibrium (Henry coefficient). The influence of packing dimensions, pH, water flow rate and discharge rate was assessed as well, leading to a better insight in the operation of air scrubbers.

To validate the simulation results, a measurement campaign will be conducted in May 2014 at a full-scale chemical air scrubber. Inlet and outlet concentrations of ammonia, hydrogen sulphide, nitrous oxide and methane will be monitored using a photo-acoustic gas monitor (INNOVA) and H_2S will be measured using gas detection tubes. The washing water will be analyzed for ammonium and sulphate concentrations. The validation results will be presented at the symposium.

Keywords: air scrubbers, optimization, modeling, simulation, ammonia

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