

# Optimised NO<sub>x</sub> Abatement Strategy Using Ionic Liquids

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NO<sub>x</sub> formation as a side product of high temperature incineration is inevitable when air is used as oxygen source. The harmful effects of NO<sub>x</sub> gasses are well documented and include acid rain, ozone layer depletion and severe health effects (induces cell mutation and respiratory diseases among others). Due to these harmful effects, emission limits are decreasing rapidly both on land and at sea. Therefore, it is becoming increasingly important to find a viable solution to the emission concerns.

The most widely used method for NO<sub>x</sub> removal is Selective Catalytic Reduction (SCR). SCR is very efficient but also has limitations especially for mobile units due to an immense size of the installations. Furthermore, SCR uses ammonia to reduce the NO<sub>x</sub> to N<sub>2</sub>. Ammonia is a potential pollutant if it is released to the environment. Ammonia is also toxic and very corrosive adding a serious health risk to the use.

Previous work carried out by my colleagues and I introduced an alternative method in which the NO<sub>x</sub> gasses are absorbed and oxidised to nitric acid using ionic liquids (ILs). This way fossil fuel resources used to produce ammonia is saved and a potent pollutant is turned into a valuable product of commercial grade.

The end product of the process, nitric acid (HNO<sub>3</sub>), is one of the most produced chemicals on a global scale, with annual production reaching 60 million tonnes in the U.S. alone. Nitric acid is produced from ammonia, which is oxidised to NO and then oxidised further to HNO<sub>3</sub>. Therefore, directly oxidising NO in the flue gas would save 2 moles of ammonia for each mole of HNO<sub>3</sub> produced, giving a superb overall nitrogen atom efficiency.

This project presents a newly invented and patent pending design in which NO is oxidised and absorbed in two separate steps. This tandem reactor setup utilises supported ionic liquid phase (SILP) where the IL is dispersed on a porous support material. The dispersion increases the reactive surface area by several orders of magnitude and different supports can also help promote different components of the IL, thus increasing the efficiency of each single step.

Invention of the tandem process was spurred on by the discovery that absorption and oxidation in a single step has a second order dependence in NO. This means the NO concentration is squared when calculating the reaction rate (rate of formation of HNO<sub>3</sub>). Since NO<sub>x</sub> is present at rather low concentrations in a flue gas (~500 ppm), a second order dependence is very undesirable.

Splitting the processes into a pure oxidation step (preoxidation) and a pure absorption process should circumvent the second order dependence on NO and maybe even decrease it below one in the absorption process, which is the most space demanding of the two. Furthermore, it allows us to use supports which are specialised for each single step, thus improving the overall efficiency.

When the absorber in step two of the process reaches the maximum of its capacity, the HNO<sub>3</sub> is desorbed simply by heating it above 120°C. The operating temperature for the absorber should be around 30-50°C, while preoxidation should be carried out at around 100°C. In both cases, the operating temperature is significantly below the one used for SCR (300-350°C), which should decrease the energy cost of NO removal significantly.

The efficient use of the space and also the waste to value incentive should make this deNO<sub>x</sub> solution very attractive for mobile pollution sources such as the maritime industry. The maritime contribution to global NO<sub>x</sub> emissions is very severe and by some estimated to be well above 20% of the total emissions.