Environmental Sustainability Assessment & Associated Experimental Investigatations of Magnesia Production Routes

The cement industry produces Portland Cement (PC) at a rate of 3 billion tonnes/year, contributing by 5-10% to anthropogenic CO_2 emissions. The production of PC is an energy intensive and environmentally polluting process and sustainability initiatives in its production have been put forward. Among these initiatives is the development of low carbon cements such as reactive magnesia (MgO). MgO has been developed with a range of sustainability advantages over PC. However, a major concern is that the production of MgO is more energy intensive per tonne of material produced. One way of overcoming this is to explore other production routes that have the potential of being more environmentally sustainable.

Magnesia cement is currently produced by the calcination of magnesite and from processing seawater and brine. Potential production routes for MgO include its production from magnesium silicate minerals and from magnesium chloride ($MgCl_2$) solutions – a main component of waste brine – which are both targeted for their CO_2 sequestration potential. The first part of this research project provides an environmental sustainability assessment for current and potential production routes of MgO as compared to PC. The second part focuses on optimising an experimental procedure for the production of hydrated magnesium carbonates (HMCs) and MgO from the carbonation of $MgCl_2$ solutions by examining the effect of different parameters on their production. The third part investigates the application of MgO slurries in engine exhaust gas CO_2 sequestration.

The environmental sustainability evaluation shows that the production of MgO from magnesite and from seawater consumes more energy – 5.9 and 17.0 GJ/tMgO respectively – than the production of PC from calcite (4.5 GJ/t PC) however; the former production method has a lower carbon footprint than PC at 0.55 vs. 0.7 tCO_2e/t product due to its CO_2 sequestration potential. The production of MgO from magnesium silicates and $MgCl_2$ solutions also consumes more energy than that of PC however depending on the selected production route several will result in carbon negative MgO production. The advantage of producing MgO from $MgCl_2$ solutions, is that in addition to the process being carbon negative, fewer amounts of virgin raw materials are used as compared to magnesium silicate production routes.

The most significant factors that affect the optimum experimental conditions for the production of HMCs and MgO from $MgCl_2$ solutions were initial solution concentration, solution titration rates and CO_2 flow rates; where under certain conditions the reaction commenced to 99% with a CO_2 content in the HMCs as high as 37%. The optimum conditions for HMCs production taking the degree of the reaction as a primary indicator, is using a reaction temperature of 30°C with a 0.5M initial $MgCl_2$ solution concentration, titrated with ammonium hydroxide at 2.6 ml/min and a CO_2 flow rate of 250 ml/min. If the CO_2 content is taken as the primary indicator then a stirring speed of 400rpm would also be used. The reactivity of the produced MgO was comparable to commercially available MgO samples.

Reactive MgO slurries have the potential to sequester CO_2 from exhaust gas engines. The effect of the tested parameters varied depending on whether the formation of soluble magnesium bicarbonate was favoured or the precipitation of HMCs during the reaction. The parameters that significantly affected dissolution were the stirring speed, solid to liquid ratio and MgO grade; whereas, the CO_2 flow rate had the most noticeable effect on the degree of HMC precipitation. The maximum degree of reaction achieved was 87% with a maximum sequestration ratio of 1.0 $gCO_2/gMgO$.