ABSTRACT

This research focuses on the co-firing of low-quality coal with refuse derived fuel (RDF) as a means to utilise some of the abundant high-ash coal available in South Africa as a fuel co-fired with RDF in existing pulverised fuel boilers. The use of RDF is also a means to reduce the volume of waste dumped in landfill sites. The physicochemical characteristics of the RDF, run of mine coal (ROM) and discard coal were investigated, along with the co-combustion behaviour and kinetics of the RDFs, coal and their blends at different weight ratios. The blends tested contained 85%, 70%, 50% and 25% coal with the remaining proportion made up of RDF. The gaseous emissions and ash residue from the combustion of coal, RDF and coal/RDF blends were also analysed to determine the environmental impact of co-firing with RDF.

The physicochemical analysis revealed that the run-of-mine and discard coal have relatively low calorific values of 21.7 MJ/kg and 16.7 MJ/kg, respectively. The RDF samples were comprised of plastic and paper, as well as smaller amounts of other materials. The RDF sample containing mostly plastic (PL) and the other containing mostly paper (PB) were found to have higher energy contents of 31.2 MJ/kg and 22.4 MJ/kg, respectively. The thermogravimetric analysis was performed in an atmosphere of air, over a temperature range of 25 – 850°C, and the results showed that the RDF samples had lower ignition, devolatilisation, and burnout temperatures compared to the coals. The ignition temperatures for the blended fuel occurs in the lower temperature region when RDF is added to the blend, likewise the peak temperatures and burnout temperatures shifted to a lower temperature zone. The activation energies (E_a) were determined using the Coats-Redfern method. The E_a for the ROM coal of 104.4 kJ/mol, was found to reduce to 31.4 kJ/mol for 75% PB + 25% coal and 35 kJ/mol for 75% PL + 25% coal blends, respectively. The discard coal which had an E_a of 109.9 kJ/mol was reduced to 30.9 kJ/mol with the (paper blend) and 33.5 kJ/mol with the (plastic blend) for the 75% RDF + 25% coal discard blends.

The analysis of the ash for the chloride and alkali metal content in the RDFs, coal samples and their blends were determined with the use of ion chromatography and X-ray fluorescence (XRF) techniques. The co-combustion ash of discard coal and RDF showed a decrease in chloride and alkali metal content as the ratio of coal was increased in the blend. The calculated slagging and fouling indices showed that as the coal ratio in the blend increases, the propensity of the fuel to slag and foul the boiler surfaces decreases. The propensity to slag

was found to be low for the ash obtained from the co-fired blends, while the propensity to foul decreased from high to medium range for all the blends with less than 75% of the RDF PB.

The concentration of gases emitted from the combustion and co-combustion test was determined with the aid of an MGA 11 mobile gas analyzer connected online at 1 scan per second. The co-combustion of RDF with coal showed a decrease in SO_2 emissions from (387 ppm) for the discard coal to within the legislated maximum emission for South African new coal fired plants. This was attained with samples containing > 15% PL and > 30% PB RDF. The lowest SO_2 emission of 50 ppm was achieved for the blend of 25% discard coal (C2) + 75% PL. The RDF sample (PL) emitted the highest NO_x emission of 143 ppm. The peak concentration of NO_x emitted was increased with the addition of RDF during co-combustion, however, the duration of the emission was greatly reduced and all samples were within the South African standard limits. There was also an increase in the emissions of CO and CO_2 which could be due to the high volatile matter content of the RDF. The lowest CO_2 emissions was 6000 ppm and this was achieved with the blend of 85% C2 + 15% PB.

It was established in this study that the most favourable fuel blend that could be used for power generation is that of discard coal (70%) and PL (30%). This was based on the activation energy obtained from this blend, with the lowest apparent activation energies of 55.8 kJ/mol and 54.2 kJ/mol for the volatile and char combustion, respectively. This makes this blend the preferred alternative fuel to be fired in the existing pulverised fuel boilers, or other type of industrial boilers, in South Africa.