The effect of flowback water minerals on the properties of soot particles from lab-scale flares

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Abstract

Flaring operations in the oil and gas industry are an important source of soot. The properties of soot emissions affect their impact on the environment and human health. Lab-scale flares were simulated by buoyant turbulent diffusion flames at Carleton University Flare Facility. The gaseous fuel consisted of nine species, i.e., methane, ethane, propane, *n*-butane, iso-pentane, *n*-hexane, *n*-heptane, nitrogen, and carbon dioxide. Fourteen different fuel compositions were tested by changing the mole percentage of each species in the fuel, which represented the wide range of gas flare composition in the industry. The burner diameter was 50.8 mm and the fuel flow rate was 156 SLPM (standard liters per minute at 0°C and 101.3 kPa). Sodium chloride solution, surrogate solution representing flowback water from Cardium formation, and flowback water sample from Duvernay formation were atomized into droplets and were subsequently introduced into the flame to study their effect on the properties of emitted soot particles.

Several characterization techniques were used to study the properties of the produced soot particles. Size distribution of soot particles was measured using a scanning mobility particle sizer (SMPS). Effective density of soot particles was determined using a tandem arrangement of a differential mobility analyzer (DMA), a centrifugal particle mass analyzer (CPMA), and a condensation particle counter (CPC). Morphology of soot particles was studied using the tomography technique, which allows 3D imaging of soot aggregates. Primary particle diameter and aggregate size and aspect ratio at different inclination angle were obtained using this technique. Raman spectroscopy was used to study the nano-structure of soot and quantifying its graphitic and crystalline content. Chemical elements distribution was determined using the inductively coupled plasma mass spectrometry (ICP-MS) technique.

The particle size distribution results showed that the median soot aggregate size increased for heavier fuel compositions. Moreover, the primary particle diameter vary with aggregate size, but the relation is independent of fuel composition. The 3D imaging of soot aggregates revealed ring structuresin soot aggregates of any size. Primary particle diameter and area equivalent diameter obtained from 2D image analysis did not change with sample inclination angle under the TEM. The ratio between the disordered carbon and the graphitic carbon decreased for heavier fuel compositions. However, the flowback water minerals did not change this ratio. The distribution of the chemical elements showed the presence of minerals in the particle emission.