Estimation of Concentration and Quantity of Sodium Chloride Solutions on Asphalt using Infrared Spectroscopy

Wei Zhang[1], Benny Thörnberg[1] and Alex Klein-Paste[2]

1: Department of Computer and Electrical Engineering, Mid Sweden University, Sweden
2: Department of Civil and Environmental Engineering, NTNU, Trondheim, Norway

To keep winter roads safe, chemical agents are normally applied for de-icing and anti-icing purposes. Smarter and more precise spreading that accounts for local concentration variations can lower the total amount required. This work describes an optical chemometric sensor that measures both the concentration and the mass of sodium chloride (NaCl) solution on road surfaces.

Experiments were carried out in an indoor laboratory environment, where NaCl solutions of seven different concentrations were poured onto a diffusely reflecting asphalt surface, a rotating, circular shaped asphalt tile. Short-wave infrared light from a halogen filament lamp was directed onto the surface with an angle of incidence of 25° to suppress the detected specular reflection from the liquid layer surface, while maximizing the transflected signal. After a double pass through the liquid layer, the diffusely transflected light was collected by a fiberoptic coupled spectrometer, sensitive in the range 0.9 to 2.55 μm.

The background reflectance spectra of dry asphalt was acquired prior to the main experiment. Subtraction of background from measured spectra isolates the absorption caused mainly by the liquid. The pure absorbance spectra could be modelled with differential optical absorption spectroscopy (DOAS) using Beer-Lambert's law. Our DOAS model included two endmember spectra for water and dissolved sodium chloride. An overdetermined equation system, augmented by a bias term to account for residual baseline offset, yields simultaneous estimates of concentration and liquid amount.

For 21 averaged spectra, 100 measurements for each, the root mean square error (RMSE) was 2.6 % for salinity and 23.3 g/m² for solution quantity. After an additional empirical linear post-calibration, the corresponding RMSE values decreased to 1.4 % and 18.2 g/m², respectively.

The variable spectral response of various asphalt types, the suppression of ambient light, complex environmental variables such as temperature, pressure and humidity, and the limited signal-to-noise ratio are remaining challenges to be investigated for chemometric sensing in real-world, outdoor environments.