

Water uptake by soot emitted during industrial fires: physicochemical analysis and water sorption measurements

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Keywords: soot, fire, water uptake.

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Fire is the most likely hazardous risk in a nuclear facility and can lead to emissions of radioactive particles and soot in the atmosphere. Understanding and predicting the behaviour of the HEPA (High Efficiency Particulate Air Filter) filters, which are the last barriers between the atmosphere and the facility, is essential. Indeed, the clogging process of HEPA filters by soot leads to an increase of their airflow resistance and then to their potential failure. IRSN and LRGP have developed models for predicting the pressure drop of such filters by dry soot particles according to their physical properties [1, 2]. Nevertheless, in case of fire, soot particles strongly interact with gas/vapours during their transport from the fire room to the ventilation ducts. It may significantly modify the properties of the cake formed at the HEPA filter surface. A sorption model, based on the theory of multimolecular adsorption (described by the GAB equation) and the capillary condensation (Kelvin's law), has been recently developed [3] to predict the water uptake (the most likely vapour produced during fires) by ideal nanoparticles assumed to be spherical, non-porous and in point contacts. Although this model has been validated for spherical non-porous nanoparticles in point contact, its relevance for predicting water sorption on soot particles is questioning.

The principal aim of this study is to develop a model of water adsorption/condensation (AC) on soot emitted in fire conditions. This model would be developed by determining the most influencing physicochemical parameters of soot on the water sorption process. This present communication highlights the dependence of fuel type on soot structure and points out discrepancies in terms of water-soot interactions.

Experiments have been carried out with soot particles produced by combustion of isolated fuels commonly used in a nuclear facility, i.e. polymers (Plexiglas + PVC) and electrical cables, and by combustion of real gloves boxes and electrical cabinets. Characterization of particles has been performed with a Transmission Electron Microscopy (TEM) for determining the morphology (fractal structure, overlap coefficient C_{ov}), size (primary particle diameter D_{pp}) and chemical composition. The specific surface (S_{BET}) has been measured thanks to the BET method (Micromeritics 3Flex). The elemental to organic carbon ratio (Sunset Lab) and the condensed material content T_C ("Karl-Fischer" method) of soot has been also determined. Physicochemical properties of soot particles

measured according to this procedure are reported on table 1.

Table 1. Soot physicochemical properties.

Fuel	Nature	D_{pp} (nm)	C_{ov}	$S_{BET}(m^2/g)$	T_C (%)	Chemical composition
PMMA / PVC (2/3 - 1/3)	Fractal	66	0.13	57,2	25 - 35	C, O, Cl
Electrical cabinet	Compact	222	-	144,2	> 25	C, O, Cl, Zn, Br, Pb Traces: P, Sb.
Electrical cables	Fractal + Compact	68	0.05	144,2	14	C, O, Cl, Rh, Pb, Na, Fe
Gloves box	Fractal	42	0.14	43,8	5 - 8	C, N, O, Fe, Cu, Si, S Traces: F, Na, Mg, P, Cl, K, Ca, V, Ti, Cr

Water sorption isotherms have been experimentally measured with Setsys / Wetsys from Setaram and DVS Vacuum from Surface Measurement Systems. Results presented on figure 1 show that soot emitted in case of fire are more hygroscopic than those emitted by gaseous burner (CAST).

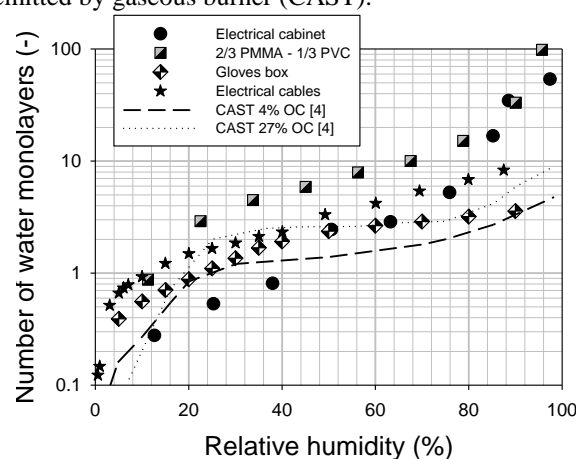


Figure 1: Water sorption isotherms for soot particles.

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