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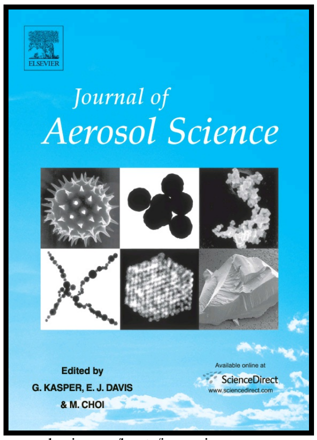

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Review on Water Electro-Sprays and applications of charged droplets with focus on the corona-assisted cone-jet mode for High Efficiency Particulate Air Filtration by wet electro-scrubbing of aerosol

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Abstract

Electrospray of Water and aqueous solutions is a simple, steady and continuous process for the production of charged droplets. Applications of this low cost spraying process, easy to scale up and environment friendly with low water consumption are first presented.

This review addresses ***the Electro-Spray (ES) in the cone-jet mode****, with focus on water ES with or without discharges in ambient air.* The physical constraints to achieve steady water electrospray in ambient air are depicted to account for Electro-Hydro-Dynamic equilibrium required for the cone and jet formation on the one hand and to control electrical discharges in the gas around the liquid (with continuous corona or without any discharge) on the other hand. Operating conditions and empirical scaling laws between regulation parameters (liquid flow rate and corona current) and the properties of droplets such as the size and the charge are presented for the corona-assisted cone-jet mode of water electrospray in air. Subsequent working conditions to achieve the other steady water ES, without discharge, are then justified. *The interest of this corona assisted cone-jet mode of electrospray in air* for the steady production of self-dispersed unipolar water droplets (close to the Rayleigh limit) with unimodal size distribution is presented with one environmental application for filtration by bipolar-scrubbing of suspended particles from exhaust or ambient aerosols*, with lab-scale efficiencies of High Efficiency Particulate Air filters***.**

Keywords: Water, Electrospray, EHD, electrical discharges, corona, wet scrubbing

1 Introduction

The fragmentation of bulk liquid into droplets is used in various fields of science and technology under different key-words; ‘spraying’ and sometimes ‘nebulization’, ‘pulverization’ or even ‘atomization’. In all cases, the liquid is divided into droplets by fragmentation of films or jets. In pressure nebulizer, the jet is formed by applying a pressure on the liquid flowing in a capillary nozzle. Otherwise, jets can arise from liquid menisci fragmentation in turbulent gas in pneumatic atomizers or from a flat surface by mechanical deformation under external forces in piezo-electric vibrating crystals (Ashgriz, 2011). Bursting bubbles also produce droplets from liquid jet and film fragmentation, as over ocean whitecap, source of droplets and subsequent salt nuclei involved in clouds formation. (Blanchard, 1989; Rai et al., 2017).

This review addresses another spraying method with critical advantages among others; ***the Electro-Spray (ES) in the cone-jet mode****, with focus on water ES with or without discharges in ambient air.*

The interest for water drops and crystals probably arose from the unexpected shapes in permanent visible evolution. Under electrical field, the deformation is even more striking, when the more or less regular rounded drop turns into conical shapes. Since Da Vinci’s description of dripping in terms of drop mass and diameter to balance the opposed inward capillary and gravity forces (Da Vinci, 1513), Savart and Plateau’s have characterized the formation and fragmentation of neutral liquid jets into droplets by purely hydrodynamic propagation of the Plateau-Rayleigh capillary instabilities (Savart, 1833). Then, Rayleigh derived a relation between droplet and jet diameters (d_{drop}= 1.89 d_{jet}) for the axisymmetric varicose jet break-up (Rayleigh, 1879). He also demonstrated that electrical repulsions in charged liquid droplets accounts for Coulombian explosion with a size-dependent maximum charge limit (Rayleigh, 1882).

Kelvin used the ES as a Voltage generator or for printing by field driven deposition of charged droplets (Kelvin, 1867). Zeliny’s description of ES modes (Zeleny, 1917), was detailed by Vonnegut who noticed the monodispersity of droplets that can be produced in the steady cone-jet mode of ES (Vonnegut et al., 1952) from the equilibrium cone shape of conducting liquid submitted to electric field (Taylor, 1964).

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