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Laboratory and Numerical Hydraulic Modelling of Annular Pipe Electrocoagulation Reactors

Authors : Alejandra Martin-Dominguez, Javier Canto-Rios, Velitchko Tzatchkov

Abstract : Electrocoagulation is a water treatment technology that consists of generating coagulant species in situ by electrolytic oxidation of sacrificial anode materials triggered by electric current. It removes suspended solids, heavy metals, emulsified oils, bacteria, colloidal solids and particles, soluble inorganic pollutants and other contaminants from water, offering an alternative to the use of metal salts or polymers and polyelectrolyte addition for breaking stable emulsions and suspensions. The method essentially consists of passing the water being treated through pairs of consumable conductive metal plates in parallel, which act as monopolar electrodes, commonly known as 'sacrificial electrodes'. Physicochemical, electrochemical and hydraulic processes are involved in the efficiency of this type of treatment. While the physicochemical and electrochemical aspects of the technology have been extensively studied, little is known about the influence of the hydraulics. However, the hydraulic process is fundamental for the reactions that take place at the electrode boundary layers and for the coagulant mixing. Electrocoagulation reactors can be open (with free water surface) and closed (pressurized). Independently of the type of rector, hydraulic head loss is an important factor for its design. The present work focuses on the study of the total hydraulic head loss and flow velocity and pressure distribution in electrocoagulation reactors with single or multiple concentric annular cross sections. An analysis of the head loss produced by hydraulic wall shear friction and accessories (minor head losses) is presented, and compared to the head loss measured on a semi-pilot scale laboratory model for different flow rates through the reactor. The tests included laminar, transitional and turbulent flow. The observed head loss was compared also to the head loss predicted by several known conceptual theoretical and empirical equations, specific for flow in concentric annular pipes. Four single concentric annular cross section and one multiple concentric annular cross section reactor configuration were studied. The theoretical head loss resulted higher than the observed in the laboratory model in some of the tests, and lower in others of them, depending also on the assumed value for the wall roughness. Most of the theoretical models assume that the fluid elements in all annular sections have the same velocity, and that flow is steady, uniform and one-dimensional, with the same pressure and velocity profiles in all reactor sections. To check the validity of such assumptions, a computational fluid dynamics (CFD) model of the concentric annular pipe reactor was implemented using the ANSYS Fluent software, demonstrating that pressure and flow velocity distribution inside the reactor actually is not uniform. Based on the analysis, the equations that predict better the head loss in single and multiple annular sections were obtained. Other factors that may impact the head loss, such as the generation of coagulants and gases during the electrochemical reaction, the accumulation of hydroxides inside the reactor, and the change of the electrode material with time, are also discussed. The results can be used as tools for design and scale-up of electrocoagulation reactors, to be integrated into new or existing water treatment plants.

Keywords : electrocoagulation reactors, hydraulic head loss, concentric annular pipes, computational fluid dynamics model
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