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Electrofiltration technique for water and wastewater treatment and bio-products management: A review

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A B S T R A C T

Application of electric filed in filtration of water and wastewater has been reviewed in present study. Filtration media is one of the basic techniques and is a part of almost all water and wastewater treatment plants used for removal of suspended solids. Application of electrical field across the filtration media upgrades the conventional process for removal of dissolved organic carbon (DOC) in drinking water and wastewater treatment process. Moreover, combination of membrane filtration with electrical field demonstrates improvement in liquid-solid separation, permeate flux, quality of filtrate, as well as fouling control/removal. In this work, the removal of various pollutants, such as bioproduct and emerging contaminants, physical and chemical properties of dissolved, collide and suspended particles, and the effects of different parameters, like membrane properties, electrical field and water quality parameters (dissolved organic and inorganic matter, ionic strength, pH) on the efficiency of filtration are reviewed. The industrial viability, future perspective, and advantages of this technology are also investigated.

Contents

Abbreviations: COD, chemical oxygen demand; CEFS, critical electrical field strength; DC, direct current; DOC, dissolved organic compound; EC/EF, electrocoagulation/electrofiltration; EFS, electrical field strength; EMF, electro-microfiltration; ESPs, electrostatic precipitators; EUF, electro-ultrafiltration; HRT, hydraulic retention time; MBR, membrane bioreactor; MF, microfiltration; NF, nano-filtration; NTU, nephelometric turbidity unit; PCPs, personal care products; RO, reverse osmosis; SS, suspended solids; TMP, transmembrane pressure; TOC, total organic carbon; TSS, total suspended solid; UF, ultra-filtration.

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Nomenclature

A	Filter surface area
a	Constant partial radius
c	Concentration in the dispersion
c_v	Volume concentration
c_j^{∞}	Bulk concentration
d	Particle diameter
d_p	Particle size
e	Elementary charge
E	Electric field strength
E_{cr}	Critical electric field strength
E_t	Total energy consumption for cross-flow electro-filtration
E_0	Energy consumption without electric field
E_x	Additional energy consumption for water electrolysis
F_E	External electric field force
F_{es}	Electrostatic force acting on a particle
F_{ep}	Electrostatic force acting on a particle
F_{vdw}	Van der waals force for a particle plate geometry
I_x, I	Applied current
J	Solution flux at a given transmembrane pressure
k	Boltzmann constant
Na	Avogadro's number
q	Particle surface charge
r	Variable radius
R	Radial coordinate
r_o	Radius of the outer electrode
r_i	Radius of the inner electrode
r_C	Spec cake resistance
R_m	Resistance of filter medium
R_i	Hydrated ionic radius
t	Time
T	Absolute temperature
t_f	Filtration time
T_0	Retention time without electric field
T_x	Retention time with electric field
u_p	Electrophoretic mobility of the particles
V_L	Filtrate volume
V_m	Migration velocity of a particle due to the electric field
V_x	Applied voltage
x	Distance away from surface
z_i	Valance

Greek letters

Δp_E	Electroosmotic pressure
Δp_H	Hydraulic pressure
ε	Porosity
η	Dynamic viscosity
ε	Permittivity of solution
ρ	Ion packing density
ψ	Potential
$\delta Fe/\delta x$	Derivative of the free energy function at a separation distance x
η	Dynamic viscosity
λ	Correction factor
μ	Electrophoretic mobility
Δp_H	Hydraulic pressure
Δp_E	Electroosmotic pressure
$\alpha_{\alpha v}$	Specific filter cake resistance
η_L	Dynamic viscosity
J_{ave}	Average value of the flux
ε_D	Dielectric permittivity of water
μ	Viscosity of water
κ	Concentration factor
φ_o	Electric potential at the outer electrode
φ_i	Electric potential at the inner electrode
σ	Solution conductivity

1. Introduction

Water more or less contains excess chemical and biological compounds, as well as pathogens, which must be eliminated; hence, the sequence of physical separations (sedimentation or flotation), coagulation by chemical additives such as iron or aluminum salts, flocculation by polymers, filtration, and adsorption are among the basic processes of each water treatment plant. Neutralization of ordinary negative charges enhances the efficiency of treatment in coagulation/flocculation and filtration processes. However, utilization of the chemical additives and backwashing the filters produce considerable amount of solid residual or sludge discharged into landfills or wastewater collectors. Nowadays, advanced technologies are seeking more provident and efficient treatment by minimizing the chemical additives, simplifying the process, and reducing the amount of sludge. Many of those techniques exploit additional driving forces such as, acoustic, magnetic, thermal and electrical fields [1]. So, using this technology leads to minimization of the chemical additives dosage and reduction in residuals generation, and thereby, decrease in cost of chemicals and waste disposal [2]. Application of electrical field for enhancement of efficiency of filtration firstly proposed by Bechold in 1925 [3], later it was used in non-aqueous media, such as separation of fine particles from petroleum oil [4]. Introduction of high voltage electrical field was well established for removal of airborne particles in processes such as electrostatic precipitators (ESPs); however, the technical improvement in operating conditions of filtration makes electro-filtration a promising method for water and wastewater treatment [2,5]. Strict regulation on the maximum concentration of micro-pollutants drives some studies to investigate electro-filtration reliability for removal of micro-pollutant like personal care products (PCPs) [6] or titanium dioxide (TiO_2) [7]. Increasing landfilling and cost of sludge treatment are the other driving factors for installation of electric technology in conventional sludge treatment and dewatering processes [8]. These reasons led to electrical field implementation in deep bed filtration, dead-end or joint filtration with different membrane processes [9,10]. This review addresses application of electrical filed in water and wastewater treatment considering the characteristics and advantages of this method in media and membrane filtration techniques. Fig. 1a shows the general view of electrofiltration set up which can be divided in two general categories (in media and membrane electrofiltration), and Fig. 1b shows effective parameters, advantages and application areas of this technique. The following sections illustrate the principle, operation, application, and effective factors of electrofiltration.

2. The principal

Electrofiltration is a process which is able to minimize membrane fouling by employing direct current (DC) electrical field across the filtration system. Except ions, almost all colloids and suspended solids (SS), even microorganisms, have mainly negative or positive electrical charge; therefore, in the presence of electrical field, they deviated. Electrical field can be configured properly for either attraction of undesired particles to media collectors, or ward