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Boron in Produced Water: Challenges and Improvements: A Comprehensive Review

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Abstract: Boron concentration in produced water is significantly high. Produced water is water trapped in underground formation that is brought to surface along with oil and gas during drilling. Because this water has been in contact with the hydrocarbon formation for centuries, it now contains some of the characteristics of the formation as well as the hydrocarbons itself. Concisely, boron concentration in produced water makes produced water unusable if not properly removed. The World Health Organization (WHO) regulation guidelines for discharge of water into the environment set boron concentration at 0.5 mg L^{-1} for potable water. Many technologies have been developed to remove boron from produced water. However, there have been series of reported limitations based on the molecular weight of boron as well as its ionic dissociation constant. The health implication of boron consumption is enormous because according to the medico-biological investigations, boron compounds belong to the second class of the toxicological danger. The purpose of this study is to make an extensive review on published literatures on boron removal technologies in general, parameters that affect the efficiency of different treatment technologies, its importance, toxicity, deficiency and dissociation constant.

Key words: Adsorption, biological treatment, boron, electrocoagulation, electrodialysis, integrated system, ion exchange, parameters, reverse osmosis

INTRODUCTION

Produced water includes water trapped in underground formations and water injected into the stratum to drive out the crude oil (Deng *et al*., 2002). It is separated from crude oil above ground in an oil/water separator (Murray-Gulde *et al*., 2003). In early stages of oil production, water content is usually low but can rise to as high as 80% during the later years of the well (Lu *et al*., 2006). Produced water is the largest waste-stream of oil and gas exploration. Global produced water production is estimated at about 250 million barrels per day compared with about 80 million barrels per day of oil (Fakhru'l-Razia *et al*., 2009). The chemical composition and behavior of produced water varies when compared with the surface waters because they are constrained within an aquifer (Wemedo *et al*., 2009). Produced water has distinctive characteristics due to the presence of organic and inorganic matters, high salinity, BTEX, PAH, etc. which can cause toxicity to the environment. Naturally, produced water contains various microorganisms which result in microbial corrosion of the inner surfaces of pipes and related systems conveying the water. Such microbial corrosion process occurs by formation of biofilms on the metal surfaces (Puyate and Rim-Rukeh, 2008). The constituents of produced water vary and can differ from well to well (Cakmakce *et al*., 2008). The pH of produced water is about 6-8.5 (Cakmakce *et al*., 2008; Veil *et al*., 2004) while boron concentration in produced water is about 26-28 ppm (Cakmakce *et al*., 2008). Produced water is increasingly being considered as a way to supplement limited freshwater resources in many parts of the US as well as other countries (Xu *et al*., 2008). Therefore, effective treatment method should be employed to treat this essential water for reuse and irrigation purposes especially in arid areas where farmers experience water scarcity.

Boron is a commonly known drinking water contaminant that affects the reproductability of living organisms (Dydo *et al*., 2005). In nature boron appears mostly as boric acid (H_3BO_3) and borax, ($Na_2B_4O_7.10H_2O$). In aquatic systems, it exists primarily as undissociated boric acid and borate ions (Bryjak *et al*., 2008). The main sources of boron in surface water are urban wastewater containing detergents and cleaning products, industrial effluents and chemical products used in agriculture (Liu *et al*., 2009a). When water with high boron concentration is used for irrigation, boron compounds form complexes with heavy metals like Pb, Cu, Co, Ni, Cd etc. and increase the potential toxicity of these

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