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Survey efficiency of electrocoagulation on nitrate removal from aqueous solution

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ABSTRACT: Water supply for consumption is one of the crucial objectives of water supply systems. Using of excessive fertilizer is a main source of nitrate content in water. The high amounts of nitrate in water have a determinable effect on the environment which must be removed due to drinking and industrial water standards. The purpose of this study is nitrate removal from aqueous solution by Electrocoagulation process. The applied pilot was comprised of a reservoir, electrode and power supply. In this study pH, electrical potential difference, nitrate initial concentration, total dissolved solid , kind of electrode, electrode connection methods and number of electrode were studied. Moreover, obtained optimum conditions were tested on Kerman water. The results showed that the electrocoagulation process can reach nitrate to less than standard limit. pH, electrical potential difference, total dissolved solids and number of electrodes have direct effect and initial concentration of nitrate has reverse effect on nitrate removal. This study also showed that under optimum condition, nitrate removal from Kerman water distribution system was 89.7 %. According to the results, Electrocoagulation process is suggested as an effective technique in nitrate removal.

Key words: *Electrode materials; Kerman water; Monopolar; Water treatment*

INTRODUCTION

Pollution of water resources by nitrate is occurred due to domestic wastewaters and unconventional consumption of fertilizers in agricultural (Horold *et al*., 1993; Pintar *et al*., 2001; Mahvi *et al*., 2005; Nouri *et al*., 2008; Atafar *et al*., 2010). Nitrogen containing compounds create serious problems including eutrophication, destroyed water quality and potential hazards on human and animal health when they enter to water resources (Nouri *et al*., 2006; Ghafari *et al*., 2008; Igbinosa and Okoh, 2009). Increased intake of nitrate affects health by creating of methemoglobinoma in children, hypertension, thyroid disability and carcinogenicity hazard of nitrosamine and nitrosamide (Hell *et al*., 1998; Luk and Au-Yeung, 2002; Vosoughifar *et al*., 2005; Ayyasamy *et al*., 2007; Ghafari *et al*., 2008;). The WHO guideline values are 50 mg/L as NO_3 for nitrate and 3 mg/L as NO_2 for nitrite, with a further provisional value of 0.2 mg/L as NO_2 for nitrite based on chronic effects(Horold *et al*., 1993; Twort *et al*., 2000; Ghafari *et al*., 2008). The conventional methods for nitrate removal are ion exchange, biological treatment, reverse osmosis, coagulation process, activated carbon absorption, nitrification by ozonation (Lin and Wu, 1996; Bae *et al*., 2002; Paidar *et al*., 2002; Koparal and Ogutveren, 2002; Pintar *et al*., 2001; Aslan and Turkman, 2006; Nabi Bidhendi *et al*., 2006; Bandyopadhyay and Chattopadhyay, 2007; Igwe *et al*., 2008; Babel *et al*., 2009). Electrocoagulation process has been successfully employed for color, heavy metals and COD removal of industrial wastewaters (Lin and Wu, 1996; Emamjomeh and Sivakumar, 2009; Schulz *et al*., 2009). Electrocoagulation process has some advantages such as no need to chemical materials, no sludge production, need to small space and low investment costs (Koparal and Ogutveren, 2002; Hu *et al*., 2003; Kobya *et al*., 2006).

Electrocoagulation process involves applying an electric current to sacrificial electrodes (mostly iron and aluminum) inside a reactor tank where the current generates a coagulating agent and gas bubbles (Xiong *et al*., 2001; Kim *et al*., 2002). This process has three stages: 1) coagulants formation due to anode electrical

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oxidation, 2) destabilizing pollutants and suspended substances and emulsion breaking and 3) combining instable particles to form floc (Xiong *et al.*, 2001; Koparal and Ogutveren, 2002; Ramesh *et al.*, 2007; Ghernaout *et al.*, 2008).

Destabilization mechanisms in this process include electrical double layer compression, adsorption and charge neutralization, enmeshment in a precipitate and inter-particle bridging (Kim *et al.*, 2002; Abdel-Ghani and Elchaghaby, 2007; Drouiche *et al.*, 2008; Abdel-Ghani *et al.*, 2009; Zvinowanda *et al.*, 2009).

When iron or aluminum are used as electrode, trivalent iron or aluminum are produced which will react with hydroxyl ions and produce metal hydroxide and polyhydroxide ions (Ramesh *et al.*, 2007). Electrocoagulation reactors could be operated by up or counter current flow or monopolar and dipolar connection (Jiang *et al.*, 2002). The study was performed in Kerman province located in the south-eastern part of Iran with longitude 54º, 21´- 59º, 34´ and latitude of 26º, 29´ - 31º, 58´, is characterized by warm and arid climate and considerable temperature variations between day and night (Malakootian and Dowlatshahi, 2007) The aim of this study was to determine the performance of Electrocoagulation process in nitrate removal and obtain optimum conditions.

MATERIAL AND METHODS

The experimental set-up used in the study was shown in Fig.1. The dimensions of electrodes were 100× 100 × 2mm. Fat removal of electrodes surface was accomplished by acetone. A magnetic stirrer has been applied for mixing (300 rpm). In all stages of the study, the electrical potential differences and current intensities were measured by voltmeter and ohmmeter, installed on circus, respectively. The synthetic aqueous solution was prepared by potassium nitrate and deionized water. In all stages of the study, sodium chloride was added to solution due to low electrical conductivity.

In this study pH, electrical potential difference, nitrate initial concentration, total dissolved solid (TDS), kind of electrode, electrode connection methods and number of electrode were studied. Moreover, obtained optimum conditions were tested on Kerman water. For this purpose, first Kerman water quality was analyzed and the results are including pH=7.43; 1.2 g/LTDS; 75 mg/L Na; 7 mg/L K; 395 (mg/L as $CaCO_3$) hardness and 274 (mg/L as $CaCO_3$) alkalinity. Kerman water nitrate concentration was increased up to the value of 100mg/L by adding KNO_3 (the amount that determined in groundwater of Iran).

All stages of experiment were performed at time 12, 24, 36, 48 and 60 min. Analyses were performed according to the standard methods for examination of water and wastewater (APHA, 1998).

RESULTS AND DISCUSSION

Effect of pH

pH is an effective factor on Electrocoagulation process performance (Fig. 2). The nitrate removal efficiency increases with increase of pH. This can be attributed to the reaction between metal and hydroxide ions. The results of this study have been confirmed by Malakootian and Yousefi on removal of hardness from water by electrocoagulation and Koparal on Removal of nitrate from water by electroreduction and electrocoagulation and Bazrafshan *et al* on removal of chromium (VI) by electrocoagulation (Koparal and

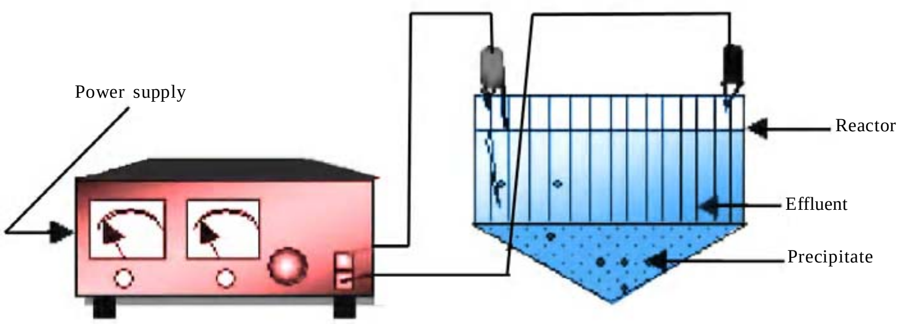

Fig. 1: Schematic of electrocoagulation pilot plant

Ogutveren, 2002; Mavrov *et al., 2006;* Bazrafshan *et al.*, 2007; Malakootian and Yousefi, 2009). As Fig. 3 represents, with increase of the electrical potential difference, the nitrate removal efficiency increases. This is due to more flocs production in high voltage. These results also are in line with the pointed results of research in Iran and the results of Ranta Kumar *et al* in India in relation to removal of arsenic from water by electrocoagulation and Koparal on removal of nitrate from water by electroreduction and electrocoagulation and Lin *et al* in China on electrochemical removal of nitrite and ammonia for aquaculture and Hu *et al* in Thailand in relation to effects of co-existing anions on fluoride removal in electrocoagulation (EC) process using aluminum electrodes and Ugrulu on removal inorganic compound by electrocoagulation (Lin and Wu, 1996; Koparal and Ogutveren, 2002; Hu *et al.*, 2003; Ratna Kumar *et al.*, 2004; Ugurlu ,2004; Bazrafshan *et al.*, 2008; Malakootian and Yousefi, 2009)

Effect of nitrate initial concentrations

With increase nitrate initial concentration, the nitrate removal efficiency decreases (Fig. 4). Also, with increase nitrate initial concentration, the requirement time for achieves the desired amount of nitrate remaining increases. The results of this study have been confirmed by the results of the Bazrafshan *et al* study in Iran and Drouiche *et al* in Algeria on electrocoagulation treatment of chemical mechanical

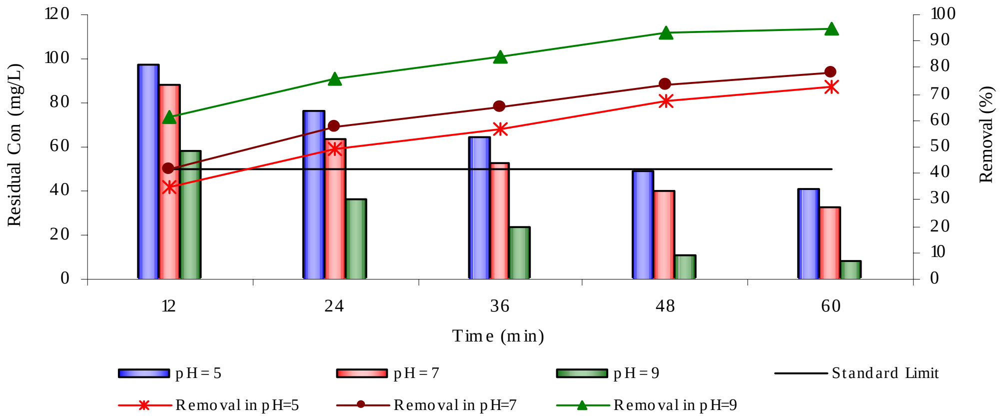

Fig. 2: Effect of pH on the efficiency of nitrate removal (20 V, TDS= 2g/L, 150 mg/L nitrate initial concentrations, aluminum electrode, three electrode pairs)

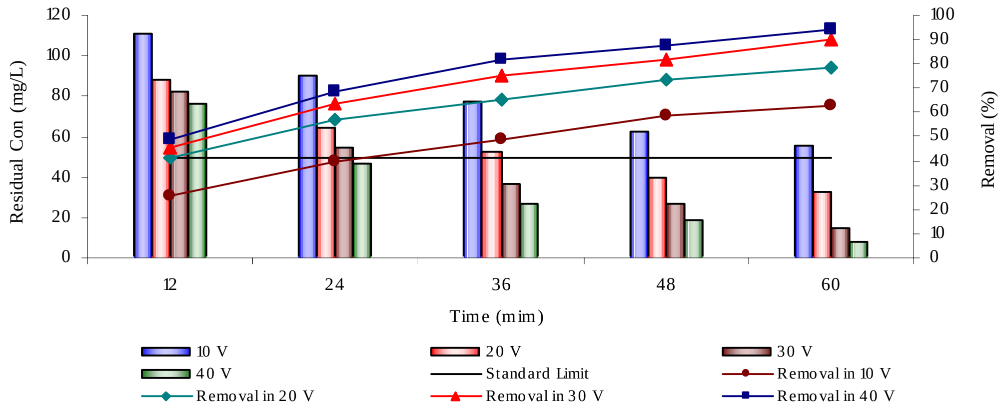

Fig. 3: Effect of different potential on the efficiency of nitrate removal (pH=7, TDS =2g/L, 150 mg/L nitrate initial concentrations, aluminum electrode and three electrode pairs)

polishing wastewater : removal of fluoride – sludge characteristics – operation cost and Koparal on removal of nitrate from water by electroreduction and electrocoagulation, Kashefialasl *et al* in Iran on treatment of dye solution containing colored index acid yellow 36 by electrocoagulation using iron electrodes and Lin *et al* in China for electrochemical removal of nitrite and ammonia for aquaculture (Lin and Wu, 1996; Koparal and Ogutveren, 2002; Kashefialasl *et al*., 2006; Bazrafshan *et al*., 2008; Drouiche *et al*., 2008;).Fig. 5 showed that with increase of the concentration of TDS, the nitrate removal efficiency increases. It's referred to this fact that with increase of the TDS (electrical conductivity), the electrical current and floc production increases and subsequent nitrate removal efficiency increases. The results of this study by Lin and wu study in China was consistent(Lin and Wu, 1996).

Effect of electrode number

Fig. 6 showed that with increases in electrode number, the nitrate removal efficiency increases. It can be due to more consumption of energy and then production more flocs in shorter time. This results has been also confirmed by Lin in China (Lin and Wu, 1996).

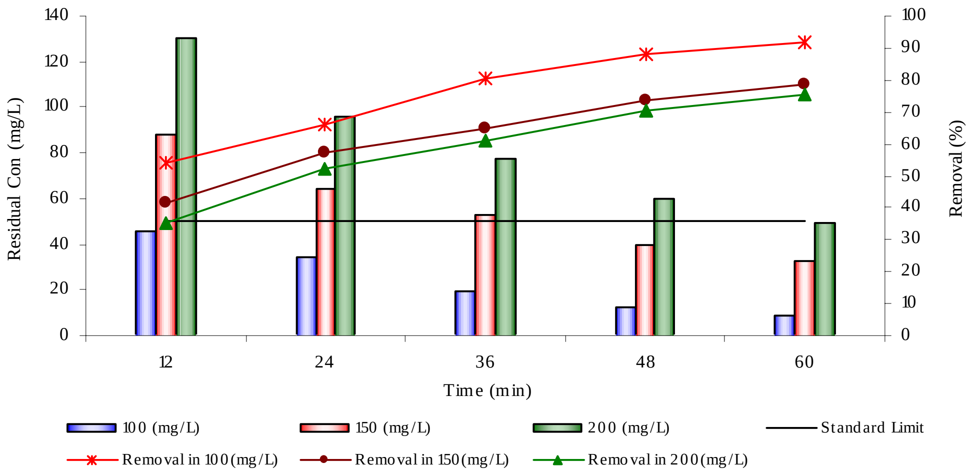

Fig. 4: Effect of nitrate initial concentration on the nitrate removal efficiency (pH=7, 20V, TDS=2g/L and three pairs of aluminum electrodes)

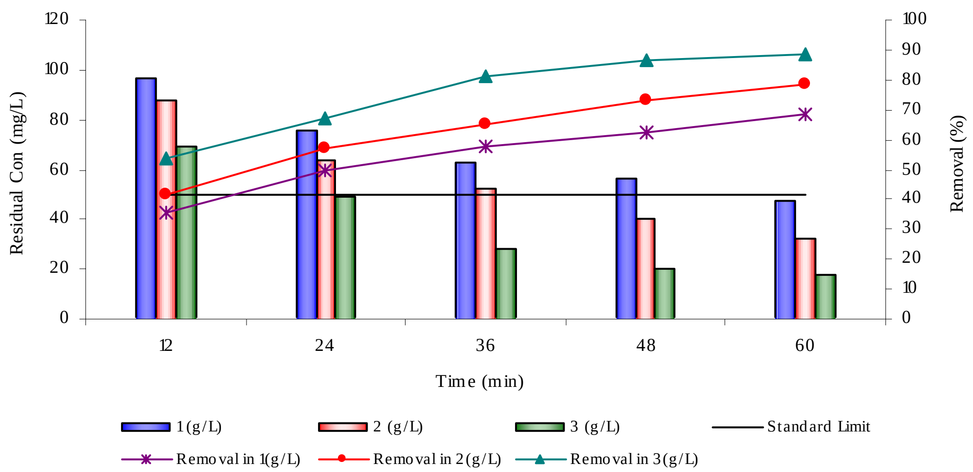

Fig. 5: Effect of TDS on the nitrate removal efficiency (pH=7, 20 V, TDS=2g/L and three pairs of aluminum electrodes)

Effect of electrodes connection methods

According to Fig. 7, the nitrate removal efficiency with monopolar connection was higher than the bipolar electrodes connection method. It can be due to more consumption of electric energy in the monopolar connection and more production of flocs in shorter time. But more energy consumption will be followed.

Effect of electrode kind

Fig. 8 showed that iron electrodes have more efficiency in nitrate removal than aluminum electrodes. It can refer to high density of iron hydroxide ions than aluminum and this has also been conflicted by Rahmani in his study in Iran about removal of water turbidity by the electrocoagulation method (Rahmani, 2008). It should be mentioned that using Iron electrodes has limits due to the production of color(Kawamura, 2000).

Effect of electrocoagulation process on Kerman water

Fig. 9 showed the results of nitrate removal from Kerman water distribution system in experiment optimum conditions (pH=7.43, electrical potential

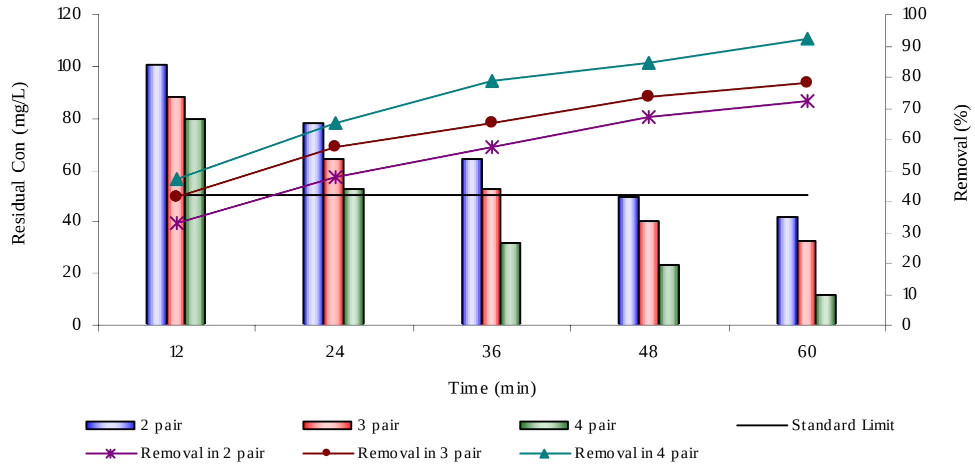

Fig. 6: Effect of electrode number on the nitrate removal efficiency (pH= 7, 20 V, TDS= 2g/L, 150 mg/L nitrate initial concentrations)

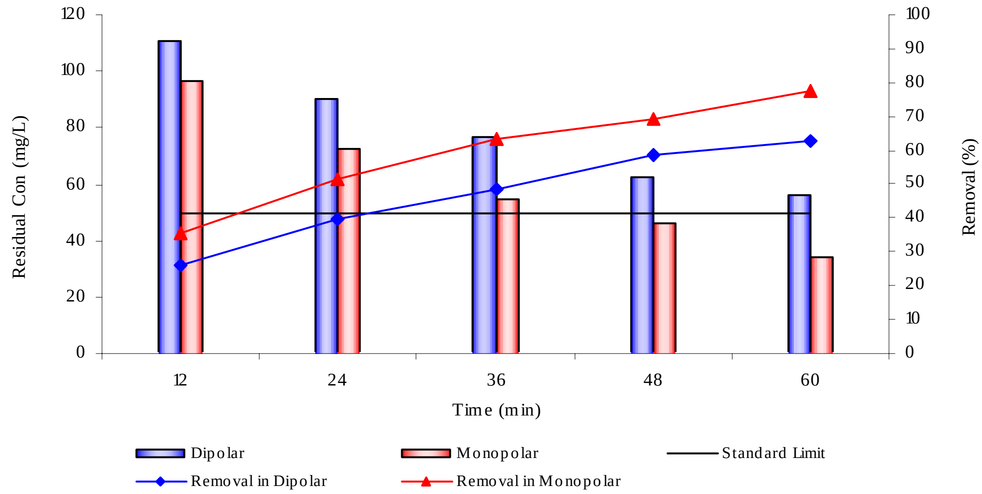

Fig. 7: Effect of electrodes connection method on the efficiency of nitrate removal (pH=7 , 10 V, TDS=2g/L, 150 mg/L nitrate initial concentrations)

difference 40V, TDS=1.27g/L, iron electrodes, bipolar connection method and four electrode pairs) that the amount of nitrate was increased to 100 mg/L as NO_3. Due to no need to chemical material before and after electrocoagulation process, the water pH didn't change and the pH of water distribution system was surveyed in the experiment stage of Kerman water distribution system. Moreover, due to the amount of TDS were relatively sufficient to experiment and with increases of TDS, the amount of its will be higher than drinking water standard (TDS standard is 1500 mg/L), in this regard, the amount os TDS was not changed in Kerman water distribution system. In addition, the bipolar connection was used because of the bipolar connection has less energy consumption to reach the standard limit than monopolar connection.The results showed that pH, electrical potential difference, TDS and number of electrodes have direct effect and initial nitrate concentration has reverse effect on efficiency of nitrate removal. The effectiveness of this process with study optimum conditions (pH=7.34, electrical potential difference 40V, initial concentration of nitrate 100 mg/

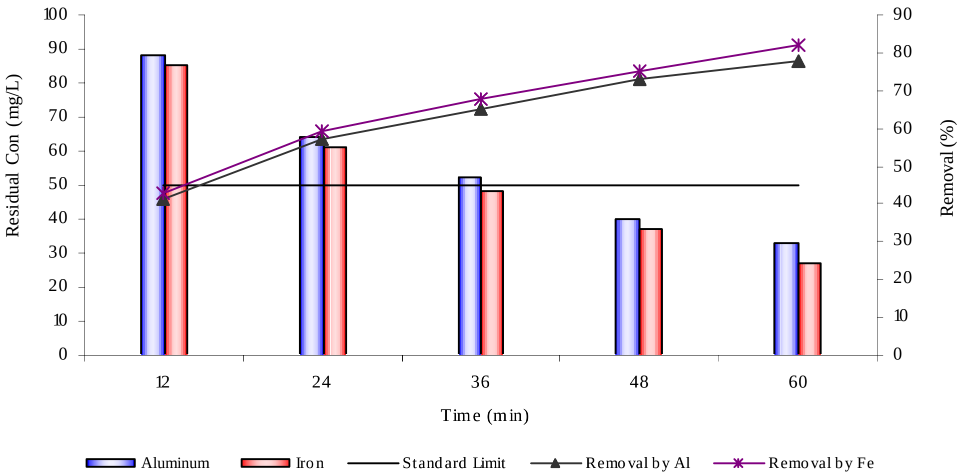

Fig. 8: Effect of electrode kind on the nitrate removal efficiency (pH=7, 20 V, TDS=2g/L, 150 mg/L nitrate initial concentrations)

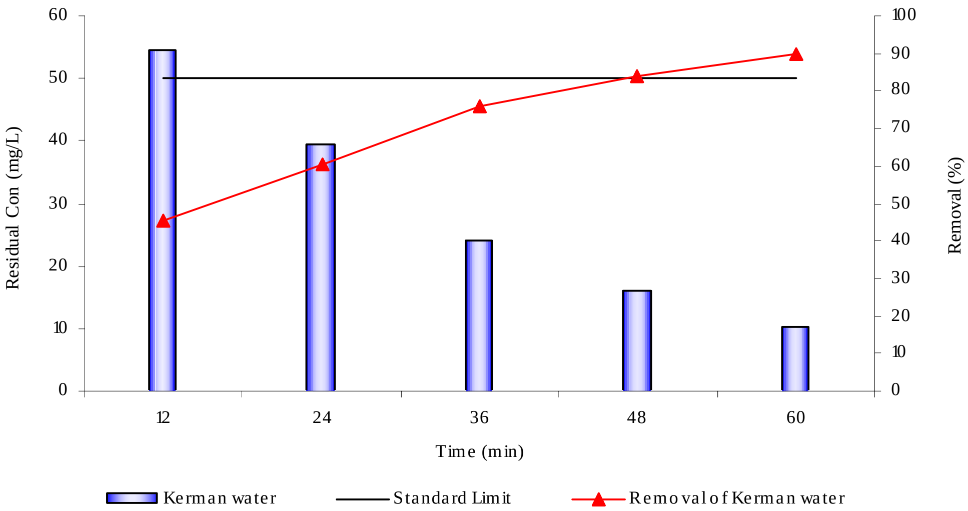

Fig. 9: Nitrate removal efficiency of Kerman water distribution system

L, TDS=1.27g/L, iron electrode and 4 pairs of electrodes) on nitrate removal from the Kerman water distribution system showed that the nitrate removal efficiency was 89.7%. Therefore, this process is suggested as an efficient alternative technique on nitrate removal from aqueous solution.

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