B－4 BIOLOGICAL AND ELECTROCHEMICAL REACTIONS IN A DENITRIFYING BIOFILM-ELECRODE REACTOR

Z. Feleke , Y. Sakakibara , K. Araki , T. Watanabe and M. Kuroda, Department of Civil Engineering , Gunma University , Kiryu , Gunma, 376 , Japan.

1. INTRODUCTION

Nitrate pollution of ground water is becoming one of the serious environmental problems in many parts of the world. The most common causes of this pollution are the excessive use of fertilizers in intensive agriculture and discharge of domestic and animal wastes. Concern for possible health consequenses has led to the adoption of a guideline value (10 mgNO_3^--N/l) in water for human consumption [1].

Several physical, chemical and biological processes have been proposed to reduce nitrate concentration in drinking water , but their performance is affected by several factors including the presence of other ions such as sulfate and chloride [2] . Among the techniques, biological denitrification is a process by which denitrifying microorganisms convert nitrate into nitrogen gas by using an appropriate hydrogen donor. In this study, denitrification performance of the biofilm - electrode system in the presence of sulfate, chloride and other ionic constituents was investigated. Three biofilm - electrode reactors , were operated in a continuous mode under different electric current conditions and predominant reactions which might affect the performance were evaluated.

2. BIOFILM-ELECTRODE SYSTEM

In the biofilm-electrode system, hydrogen is produced by electrolysis of water and denitrifying microorganisms were immobilized on the surface of the cathode [4]. Previous studies [5,6] showed that , by applying an electric current, denitrification can be achieved with simultaneous neutralization by carbon dioxide produced at the anode ; based on the following electrochemical and biological reactions,

At the anode,

$$C + 2H_2O = CO_2 + 4H^+ + 4e^- \quad (e^\circ = 0.207V) \quad (1)$$
$$H_2O = 1/2O_2 + 2H^+ + 2e^- \quad (e^\circ = 1.23V) \quad (2)$$
$$2Cl^- = Cl_2 + 2e^- \quad (e^0 = 1.36V) \quad (3)$$

At the cathode,

$$1/2O_2 + H_2O + 2e^- = 2OH^- \quad (e^0 = 0.401V) \quad (4)$$
$$2H_2O + 2e^- = H_2 + 2OH^- \quad (e^0 = 0.0V) \quad (5)$$

Where e^0 is the standard electrode potential. Reactions with lower anodic and/or higher cathodic potential are predominant in electrochemical systems . It is thought that, after DO is reduced reactions (1) and (5) become predominant at the anode and cathode, respectively. Hydrogen which is produced by reaction (5) can be utilized for denitrification according to the following net denitrification reaction [3] .

$$2NO_3^- + 5H_2 = N_2 + 4H_2O + 2OH^- \quad (6)$$

3. MATERIALS AND METHODS

Figure 1 shows a schematic representation of the experimental apparatus used in this study. Three identical reactors consisted of an amorphous carbon anode, a stainless cathode on which denitrifying microorganisms were immobilized by using a porous matrix (polyurethane foam) and a DC power supply. Effective liquid volume and surface area of the cathode were 0.205 L and 251 cm^2, respectively. HRT was maintained at about 10hrs. 20mg/l nitrate-nitrogen and a slight amount of inorganic nutrients were added into a well water which originally contains low concentration of these constituents. The ground water was fed into the reactors and measurements were made for the influent and effluent ionic constituents with an ion chromatograph (IC 7000 Series II, Yokogawa Analytical Systems).

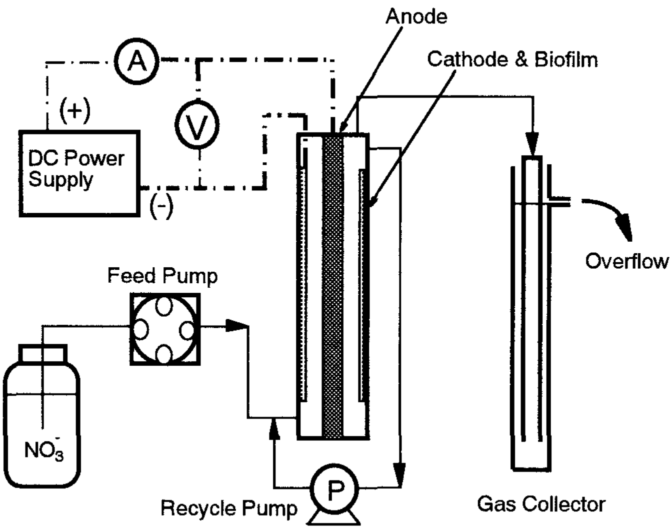

Figure 1 Schematic Representation of Experimental Apparatus

3. RESULTS AND DISCUSSION

Figure 2 shows the experimental results of effluent nitrate and sulfate concentrations at different electric current. As shown in the figure, denitrification performance of the reactors depends on the electric current, but sulfate and chloride (which is not indicated in this figure) concentrations were not affected by either electrochemical or biological reactions. Table 1 shows mean influent and effluent concentrations of ionic constituents measured in this study. Most of the ions were not affected by the applied current or by the biological reaction with the exception of calcium and magnesium. The decrease in concentration of calcium and magnesium ions is probably attributable to precipitation reactions near the cathode.

Table 1. Mean Influent And Effluent Concentration of Ionic Constituents (HRT = 10hrs, I= 2.0 ,3.5mA)

Ion	Mean Concentration (mg/l)			
	Influent	Std.Dev.	Effluent	Std.Dev.
Cl^-	17 6	1.5	17.3	1.7
SO_4^{2-}	8.1	0.6	7.6	0.5
PO_4^{3-}	1.9	0.4	1 7	0.6
NO_2^-	0.0	0.0	0.3	0.6
Na^+	49 4	2.7	48.3	2.8
K^+	8.0	0.9	8.0	1.0
Ca^{2+}	23.5	1.6	19.1	4 7
Mg^{2+}	8.5	0.5	6 4	1.2
NH_4^+	ND	-	ND	-

However, it is thought that production of carbon dioxide at the anode maintain the pH around neutrality and thereby prevents excess precipitation of calcium and magnesium. Ammonia was never detected in the reactors, but nitrite appeared in most cases at lower concentration. Despite stoichiometrically expected amount of nitrate removed, pH was maintained nearly constant by the neutralization reaction. Gas production rate is lower than the stoichiometric value for the applied current condition, mainly due to continuous dissolution of nitrogen gas into the bulk liquid.

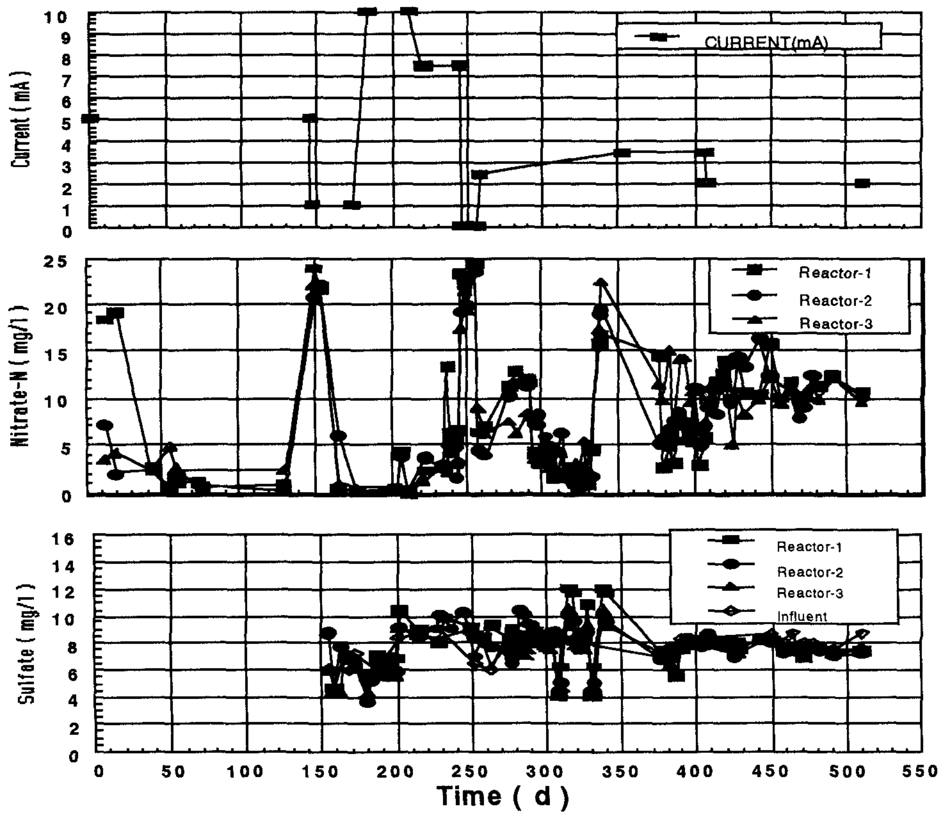

Figure 2 . Performance of denitrification and Sulfate profile at different applied current condition

4. CONCLUSION

Efficient denitrification was achieved using biofilm-electrode reactor without oxidation of chloride at the anode and reduction of sulfate by the microorganisms. Slight decreases in concentration of calcium and magnesium were observed. However, it is thought that neutralization by carbon dioxde produced at the anode maintained the pH around neutrality and prevents excess precipitation.

5. REFERENCES

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