World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:4, No:2, 2010

Open Science Index, Environmental and Ecological Engineering Vol:4, No:2, 2010 publications.waset.org/670.pdf

Effect of Influent COD on Biological Ammonia Removal Efficiency

S. H. Mirhossaini, H. Godini, and A. Jafari

Abstract**—**Biological Ammonia removal (nitrification), the oxidation of ammonia to nitrate catalyzed by bacteria, is a key part of global nitrogen cycling. In the first step of nitrification, chemolithoautotrophic ammonia oxidizer transform ammonia to nitrite, this subsequently oxidized to nitrate by nitrite oxidizing bacteria. This process can be affected by several factors. In this study the effect of influent COD on biological ammonia removal in a bench-scale biological reactor was investigated. Experiments were carried out using synthetic wastewater. The initial ammonium concentration was 25mgNH_4^+-N L^{-1}. The effect of COD between 247.55±1.8 and 601.08±3.24mgL^{-1} on biological ammonia removal was investigated by varying the COD loading supplied to reactor. From the results obtained in this study it could be concluded in the range of 247.55±1.8 to 351.35±2.05mgL^{-1}, there is a direct relationship between amount of COD and ammonia removal. However more than 351.35±2.05 up to 601.08±3.24mgL^{-1} were found an indirect relationship between them.

Keywords**—**Ammonia biological removal, Nitrification, Influent COD.

I. INTRODUCTION

SEVERAL activities generate high-strength ammonia wastewater including human waste, agricultural waste and industrial effluent. Uncontrolled disposal of these effluents can cause great damage to the environment, primarily through eutrofication of receiving waste and because ammonium freely dissolved in the water is one of the worst polluting agents for aquatic life [1]. For this reason removal of ammonium from wastewater is explicitly required under the European Directive on the disposal of urban wastewater. The biological nitrogen removal (BNR) process is frequently used to treat urban wastewater. This process involves two stages: 1- conversion of ammonium into nitrate (nitrification) and 2- transformation of nitrate into nitrogen gas (denitrification).

One of the most critical parameters of the nitrification process is the influent chemical oxygen demand (COD), because it directly influences the growth competition between autotrophic and heterotrophic microorganism population [2, 3, and 4]. Some authors report that the influence of COD is greater in an aerobic activated sludge process than in the BNR process [5]. In the later case, organic matter is mainly consumed in the first anoxic stage, which apparently allows lower competition between nitrifiers and heterotrophs in the next aerobic stage. In the early 1990s, McClintock et. al. reported similar nitrification rates in both aerobic activated sludge and BNR systems operated with the same amount of COD [6]. Their results showed no differences in competition among microorganism populations in the BNR and aerobic activated sludge systems. Consequently, the influence of COD on ammonia biological removal efficiency is similar in both systems [7].

Competition among microorganisms has been clearly observed in some other biological nitrogen removal process, such as immobilized biomass systems [8]. In this case, the amount of COD causes growth competition among all different microbic populations and therefore defines the biofilm composition. This may causes undesirable biological ammonia removal inhibitions in the global process for two reasons: (1) the majority presence of heterotrophic microorganisms in the biofilm, (2) oxygen diffusion problems in immobilized biomass [9, 10].

The aim of this paper was to quantify the influence of influent COD on biological ammonia removal process for treatment of domestic wastewater. The main object of this work was to determine the optimum proportion of COD in influent wastewater in order to achieve maximum efficiency of biological ammonia removal. This study was conducted in a bench-scale reactor of extended activated sludge fed with synthetic wastewater.

II. MATERIALS AND METHODS

A. Wastewater Features

In order to prepare synthetic wastewater at different phase, certain concentration of different compounds such as $C_6H_{12}O_6$, CH_3COONH_4, $NAHCo_3$, $FeSo_4.7H_2O$, $MgSo_4.7H_2O$, $NiSo_4.7H_2O$, $CaCl_2$, $FeCl_3.6H_2O$, K_2HPo_4 [11]. The basic composition of synthetic wastewater is shown in Table I.

TABLE I
THE BASIC COMPOSITION OF SYNTHETIC WASTEWATER

component	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8
COD	247 ±1.8	302 ±0.9	351 ±2.0	401 ±3.9	452 ±2.6	492 ±14.	549 ±1.2	601 ±3.2
NH_4^+	24.7 ±0.9	24.8 ±0.1	24.1 ±0.1	24.9 ±0.1	24.9 ±0.1	24.9 ±0.1	24.9 ±0.1	24.9 ±0.1
No_3	0	0	0	0	0	0	0	0
No_2	0	0	0	0	0	0	0	0

Authors are with Department of Environmental Health, Lorestan University of Medical Science, Khoramabad, Iran (e-mail:Hmirhossaini@gmail.com).

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B. Experimental set-up

Experiments were done in an extended activated sludge laboratory reactor. The reactor was located in pilot laboratory of Isfahan University of medical sciences (in 2005). The volume of aerobic reactor was 30L and its settler volume was 10.5L (see Fig. 1). The operational temperature was kept at 25°C. The DO and pH of the aerobic reactor were kept at $3mgO_2\ l^{-1}$ and 7.7-8.1, respectively.

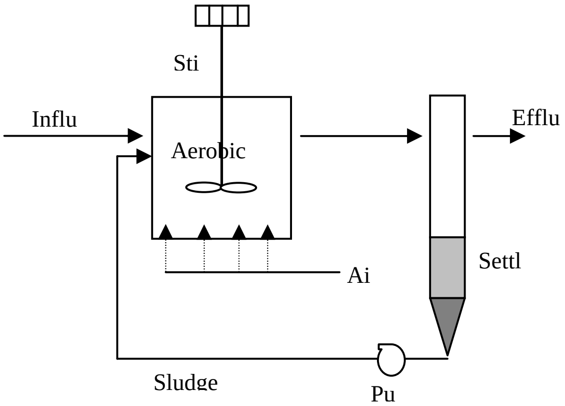

Fig. 1 Schematic diagram of the experimental set-up

C. Analytical Method

Analyses of total suspended solid (TSS), voletail suspended solid (VSS), nitrite ($NO_2^{-}N$), nitrate ($NO_3^{-}N$), Sludge volume index (SVI) and ammonium were done using the methodology described in standard methods [12]. Analyses of chemical oxygen demand (COD) were conducted through COD test tubes from Hatch and Dr. Lange [13].

III. RESULT

A. Effect of Operational Parameters

Operational parameters affecting on biological ammonia removal are divers. In order to study the influence of influent COD, parameters such as temperature, DO, pH and hydraulic resistance time (HRT) were maintained constant throughout the study. Eight different runs were performed throughout the study. In each run, a different carbon-loading rate was used (see TABLE II). TABLE III shows the influent COD concentration and ammonia removal efficiency obtained in each run. The error of each parameter was defined as the standard deviation of the average value.

Figs. 2 and 3 show the average concentrations of ammonia in influent wastewater and Figs. 4 and 5 show concentration of ammonia in reactor effluent. Fig. 6 show ammonia removal efficiency plotted versus influent COD concentration.

TABLE II
AVERAGE VALUES OF THE OPERATIONAL PARAMETERS USED THROUGHOUT THE STUDY

Run	F/M (gCODgVSS^{-1}d^{-1})	SVI (mlg^{-1})	N loading rate (gNH$_4^+$-N gVSS^{-1}d^{-1})	C loading rate (gCOD gVSS^{-1}d^{-1})
1	0.071±0.002	122±3.2	0.025	0.25±0.002
2	0.079±0.002	143±4.4	0.025	0.3±0.001
3	0.091±0.006	145±3	0.025	0.35±0.002
4	0.097±0.003	141±5.8	0.025	0.4±0.002
5	0.16±0.02	125±11	0.025	0.45±0.001
6	0.14±0.15	133±5.6	0.025	0.5±0.001
7	0.15±0.015	140±3	0.025	0.55±0.002
8	0.14±0.014	141±3	0.025	0.6±0.003

TABLE III
AVERAGE VALUES OF THE INFLUENT COD AND AMMONIA REMOVAL EFFICIENCY

Run	Influent COD (mg/l)	Ammonia removal efficiency (%)
1	247.55±1.8	21.11
2	302.27±0.96	69.26
3	351.35±2.05	79.84
4	401.24±3.95	78.05
5	452.9±2.62	46.94
6	492.74±14.03	48.45
7	549.44±1.28	17.32
8	601.08±3.24	0

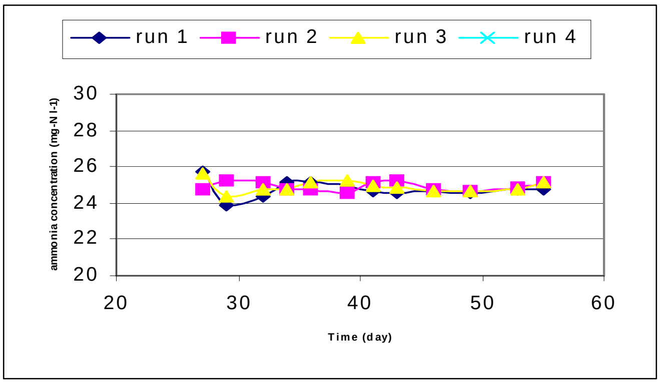

Fig. 2 Concentration of ammonia in the influent

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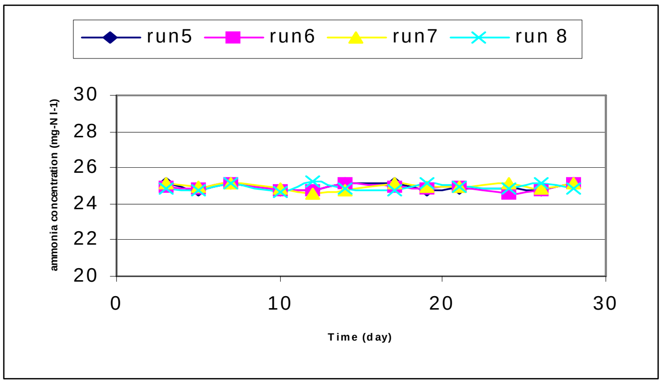

Fig. 3 Concentration of ammonia in the influent

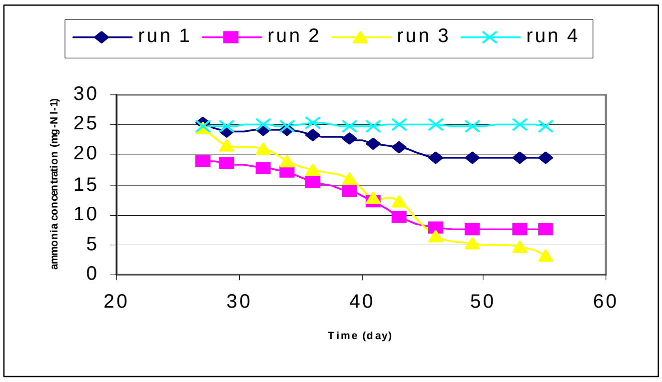

Fig. 4 Concentration of ammonia in the effluent

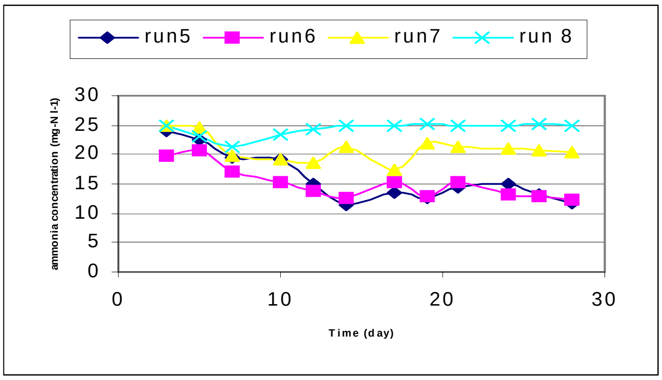

Fig. 5 Concentration of ammonia in the effluent

IV. CONCLUSION

Increased heterotrophic activity within the flasks that received glucose could have caused the contents of the flasks to go anoxic, thereby inhibiting nitrification, which is an obligatory aerobic process [14].

Overall, biological ammonia removal is highly influenced by competition established between heterotrophic and autotrophic microorganisms. This competition depends on the COD concentration in influent wastewater. The result of this study showed that the ammonia can be removed from wastewater in high quantity in extended activated sludge if COD concentration was adjusted. In influent COD concentration 351.35±2.05mgL^{-1} can remove 79.84 percent of ammonia from wastewater. When influent COD is further than 351.35±2.05mgL^{-1}, ammonia removal efficiency will decrease, Julian Carrera et al. 2004. It is showing that organic carbon in higher concentration inhabited biological ammonia removal. So there is a negative relationship between organic carbon concentration and biological ammonia removal. The similar results obtained by other researches and declared in the single- sludge system, there is a negative influence of the influent COD on the achievable biological ammonia removal [15], but in lower influent COD concentration to 351.35±2.05mgL^{-1}, there is positive relationship between organic carbon concentration and ammonia removal. Therefore a better understanding of how organic carbon influences ammonia removal may provide insight into how N cycling in wastewater is influenced by natural or anthropogenic change in organic carbon.

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