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Impact and Threshold Concentration of Toxic Materials in the Stripped Gas Liquor on Nitrification

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Abstract−The impact of the threshold concentration of toxic materials on nitrification in stripped gas liquor was investigated. Ammonia nitrogen, phenol, thiocyanide, cyanide, m-cresol, toluene, quionoline, and aniline were selected as toxic materials in the wastewater treatment experiments. The concentrations of organic materials that are contained in raw wastewater of stripped gas liquor were 400 to 600 mg/*l* phenol, 5.95 mg/*l* aniline, 17.85 mg/*l* quinoline, 197.43 mg/*l* m-cresol, and 85.57 mg/*l* toluene. When the ammonia nitrogen concentration was lower than 200 mg/*l*, the nitrification was stable. However, in the case of higher than 200 mg/*l* in the concentration of ammonia nitrogen, the removal efficiency of nitrogen was very low. Cyanide with concentration higher than 0.5 mg/*l* acted as a toxic material to microorganisms because it produced excessive foam and made the activity of microorganisms decrease. The threshold concentrations of organic materials such as m-cresol, toluene, quiline, and aniline that influence nitrification of microorganisms were 100 mg/*l*, 50 mg/*l*, and 200 mg/*l*, respectively. The change in the dilution ratio of raw wastewater and the additional amount of PAC did not make a big difference on the COD removal. On the other hand, the higher the dilution ratio of wastewater and additional amount of PAC increases, the higher the removal efficiency of ammonia nitrogen increases.

Key words: Inhibited Phenomenon, Toxicity, Toxic Material, Nitrification, Stripped Gas Liquor

INTRODUCTION

Nitrifiers are severely influenced by toxic materials which are contained in sewage or wastewater [Shrima and Ahlert, 1977; Blum and Speece, 1991; Hockenbury and Grady, 1977; Meyerhof, 1916]. The effect of toxic materials on the nitrifier can appear in a variety of forms. When toxic materials act as the inhibitor to the nitrifier, the cell growth and the ammonia oxidation are reduced. A strong toxicity causes the nitrification to be discontinued due to the disappearance of the nitrifier. However, when toxic materials are completely removed, a new nitrifier appears and then nitrification begins again.

Mayerhof [1916] experimentally investigated materials that inhibit the oxidation reaction by using the Warburg respirometer. This work reported that the factors inhibiting the oxidation reaction of nitrifier are heavy metals, traces of electrolyte that dissolved in water, a variety of organic materials, etc. It was also found that *nitrobacter* was more sensitive than *nitrosomonas* in the degree of inhibitory effect on microbes.

Painter [1970] founded that chelating agents such as thiourea, allyl thiourea, 8-hydroxy quinoline, salicyladotime, histidine, etc. showed toxicity to *nitrosomonas*. In addition, 1.0 and 10.0 mg/*l* peptone reduced microbial growth by 25 and 60%, respectively. Tomlison et al. [1966] and Dowing and Hopwood [1964] investigated the inhibitory effect of organic material on ammonia nitrification in activated sludge.

A typical electrolytes that influences nitrifying microbes is ammonium ion, free ammonia, nitrite etc. Nitrite gives impact of toxicity in the aspiration and growth of the *nitrifier* [Meiklejohn, 1954; Boullanger and Massol, 1903; Park et al., 2003]. In the case of *nitrosomonas*, when the concentration of $NaNO_3$ was 0.1 and 0.3 M, the respiratory rate of oxygen was decreased by 36% and was completely disappeared, respectively. Moreover, in the case of *nitrobacter*, this tendency is more severe. When the NO_2-N concentration is higher than 70 g/m*l*, the *nitrobacter* is difficult to be cultivated. Moreover, free ammonia is fatal to *nitrobacter*.

Heavy metals that may enter the wastewater system also have an inhibitory or toxic effect upon the treatment system, particularly upon the biological treatment processes. Heavy metals such as nickel, chromium, lead, copper cadmium, etc. can react with microbial enzymes to retard or completely inhibit the metabolism [Park et al., 2003]. Skinner and Walker [Sawyer and McCarty, 1967] reported that when nickel, chromium, and copper are 0.25, 0.25, and 0.1 to 0.5 mg/*l*, respectively, these concentrations of heavy metal completely inhibit the activity of *nitrosomonas*. Backman [Skinner and Walker, 1961] reported that when the concentration of nickel and zinc is 0.3 mg/*l*, each nitrification is completely inhibited.

The stripped gas liquor that is generated from the coal gasification process contains various organic compounds, nitrogen compounds, cyanide compounds, etc. When the stripped gas liquor is compared with general wastewater, it contains various kinds of materials that are considered as important factors with regard to the removal of nitrogen compounds such as high-strength nitrogen compounds, a variety of toxic materials, and organic materials. Moreover, it was reported that they were not thoroughly decomposed by the microorganism. Also, owing to the stripped gas liquor containing high-strength phenol and SCN, the toxicity of these materials to nitrifier should be investigated.

Free cyanide is expected to have the biggest influence on the nitri-

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fication of nitrogen compounds in the stripped gas liquor. Cyanide is classified into two forms such as free cyanide in the form of cyanide ion and complex cyanide combined with metals. The complex cyanide has very low toxicity to nitrifier, while the free cyanide has very high toxicity. Neufeld et al. [Beckman, 1972] reported that the limited concentration of free cyanide in nitrifier was 0.11 mg/*l*, but it had little difference depending on the adaptability of microorganism to toxic materials. Thus they suggested that the limited concentration of free cyanide was 8 mg/*l*.

A variety of single or complex organic compounds such as cresol, indole, toluene, quinoline, aniline, etc. are known to exist in the stripped gas liquor [Neufeld et al., 1980]. It is already found through experiments in common sewage that these materials severely disturb nitrifiers. Moreover, these materials create foam and a bad smell as well as materials that disturb the microorganism's growth.

The objective of this research was to identify the impact of the concentration of toxic materials in the stripped gas liquor on nitrification and to find the threshold concentration of the toxic materials.

EXPERIMENTAL

1. Qualitative and Quantitative Analysis of Toxic Materials

The total of 24 organic materials that are commonly known to exist in stripped gas liquor are measured by GC (Alltech, SRI 8610) and HPLC (Varian LC5500) to investigate organic materials that cause the COD and the effect of these materials on the wastewater treatment facility of microorganisms. Along with the UV Spectrum of 254 nm and the column of C_{18} used in the HPLC analysis, the separation of organic materials that adopt the proper mixing of water and methanol by the gradient program was carried out. When the 24 organic materials were analyzed by the correlation curve of HPLC, 10 organic materials were difficult to measure. Therefore, a GC with the Flame Ionization Detector (FID) and the DB-WAX Column (Alltech Cat. No. 2000170) was used to analyze them. The oven temperature in the GC is programed as follows. After staying at 35 °C for the first 10 minutes, the temperature was increased from 35 °C to 150 °C with the rate of 20 °C per min. Then, after staying at 150 °C for 15 min, the temperature was changed from 150 °C to 210 °C with an increase in 20 °C per min.

2. Respirometer of Microorganisms

The respirometer used in the experiments is the AER-200 system of Challenge Environmental System Inc. and consists of a microbial reactor, an oxygen supplier, a cell to measure flow rate, and a computer for data handling.

A microorganism reactor with a serum bottle of 250 ml is used. The gas phase volume is 100 ml because 150 ml is occupied by the liquid mixture that consists of sample and microorganisms. The actual activated sludge is cultivated in another operating reactor of activated sludge. And the uniform activated sludge taken from the above reactor is used in the experiment. The samples taken are used after the liquid mixture of raw wastewater, buffer solution, reasonable low concentration of nutrient, and microorganisms taken from the culture medium in order to uniformly adjust the concentration of the microorganism in the samples. The agitator in the serum bottle is used to carry out the mixture of the microorganism and the supply of the oxygen in the reactor. The speed of the agitator is fixed at 400 rpm so as to properly form the vortex in the reactor.

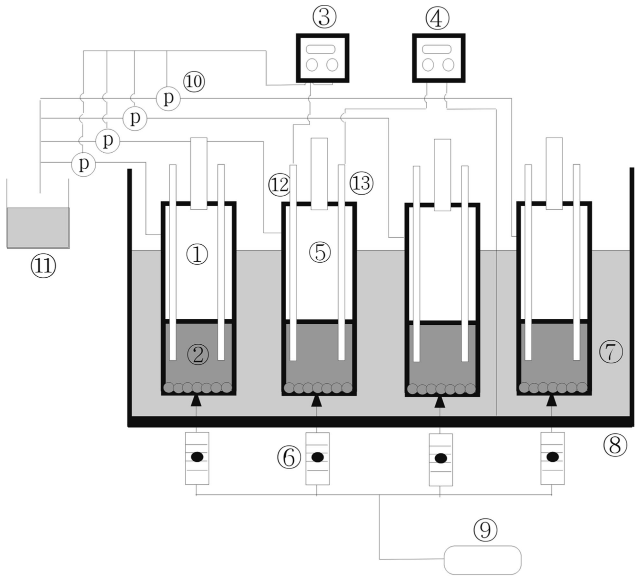

Fig. 1. Batch type reactor for the inhibition effect test of various organic toxic Compounds.

1. Reactor
2. Diffusor
3. Auto pH controller
4. PID temp. controller
5. Hood
6. Gas flow meter
7. Water Bath
8. Heater
9. Blower
10. NaOH feed pump
11. 10% NaOH tank
12. pH sensor
13. Theomost

3. Experimental Apparatus of Batch Reactor

To investigate the effect of nitrification for toxic materials that are contained in the stripped gas liquor, the apparatus shown in Fig. 1 is used. In this experiment, instead of a variety of major toxic materials that exists in stripped gas liquor, the manufactured synthetic wastewater with a different concentration is used. The concrete purpose of this experiment is to investigate the limited concentration of each toxic material that can safely treat the ammonia nitrogen which is contained in stripped gas liquor.

The concentration of ammonia nitrogen in all the reactors was 200 mg/*l*. To find out the clear limited concentration of each toxic material that affects the microorganism, the ranges of concentration for each toxic material were divided into 4 to 5 ranges. And the concentration change of each toxic material in the reactors at the beginning of the experiment was measured every 10 hrs to estimate the influence of nitrification related to the toxic materials.

Table 1. Synthetic wastewater used in batch reactor

(unit: mg/*l*)

Component	Concentration
NH_3Cl	200
$K_2HPO_4^-$	500
$MgSO_4 \cdot 7H_2O$	50
$FeCl_3 \cdot 6H_2O$	10
$CaCl_2 \cdot 2H_2O$	10
$MnSO_4 \cdot H_2O$	10
$NaHCO_3$	150

Table 2. Concentration of mineral content of the coal gasification plant's stripped gas liquor

(unit: mg/*l*)

Sample \ Material	Ca	Mg	Na	Fe	Si	P
Influent	4.12	1.84	5.23	2.25	11.31	Tr
Effluent	41.5	17.3	6.12	1.76	9.67	Tr

As seen in Table 1, the samples used in the experiment are the synthetic wastewater that has the components like NH_4Cl, K_2HPO_4, $MgSO_4\cdot 7H_2O$, $FeCl_3\cdot 6H_2O$, etc.

RESULTS AND DISCUSSION

1. Concentration of Organic and Ion Materials in the Stripped Gas Liquor

The result of qualitative and quantitative analysis for the ion materials that are contained in stripped gas liquor is shown in Table 2. The raw wastewater in the wastewater treatment facility contains materials such as Ca, Mg, Na, Fe, Si, and traces of P, which are needed for microorganism growth. Fortunately, this wastewater does not contain toxic metals such as Ni, Cr, Cu, etc. To investigate the toxic organic materials that are contained in stripped gas liquor, the influent and effluent of the biological wastewater treatment facility in a field are analyzed by the GC.

From the analysis, the organic materials contained in stripped gas liquor are aniline, 1,1-biphenyl, quinoline, isoquinoline, and 6-methyl quinoline, with their concentrations of 5.95, 24.64, 17.85, 45.89, 5.72 mg/*l*, respectively. After wastewater was treated by using microorganisms in the aeration tank, organic materials in the influent such as 1,1-biphenyl, quinoline, isoquinoline, 6-methyl quinoline, etc. were decreased or almost completely removed. Thus, 1,1-biphenyl, 6-methyl quinoline, and 2-methyl naphthalene were only detected in the final effluent, and their concentrations were 1.56, 2.95, and 0.38 mg/*l*, respectively. The results of these analyses are shown in Table 3.

The concentrations of the organic materials by the HPLC analysis are shown in Table 4. The operating conditions of HPLC are based on the ratio of methanol and water--80 : 20, 60 : 40, 40 : 60, and 20 : 80--just before or after the initial time of 0 to 5 min, 5 to 15 min, 15 to 20 min, and 20 min, respectively.

The organic materials detected in raw wastewater by the HPLC analysis are phenol, catachol, o-cresol, m-cresol, acetophone, indole, benzene, toluene, and naphthalene. Also, as seen in the final table, acetophone and indole from the final effluent were detected. Most organic materials that were detected from the final effluent were

Table 3. Concentration of organic compounds by G/C analysis

(unit: mg/*l*)

Influent		Effluent	
Aniline	5.95	1,1-biphenyl	1.56
1,1-biphenyl	24.64	6-methyl quinoline	2.95
Quinoline	17.85	2-methyl naphthalene	0.38
Isoquinoline	45.89		
6-methyl quinoline	5.72		

Table 4. Concentration of organic compounds by HPLC analysis

(unit: mg/*l*)

Influent		Effluent	
Phenol	400-600	Acetophone	4.04
Catachol	14.82	Indole	18.62
O-cresol	30.34		
m-cresol	197.43		
Acetophone	4.57		
Indole	91.36		
Benzene	15.55		
Toluene	85.57		
Naphthalene	0.17		

organic compounds of multi chains that have large relative molecular weight. They show that a very low concentration in the effluent existed even if they were incompletely decomposed in the wastewater treatment facility. It is expected that these organic materials not only have a bad effect on the BOD concentration but also act as an inhibitor to bacteria growth.

As seen in Tables 3 and 4, the stripped gas liquor involves a high concentration of organic compounds such as cresol, indole, toluene, quinoline, aniline, etc. It was reported that these materials largely have an effect on the nitrifying bacteria through the examination which was based on sewage [Meyerhof, 1916; Painter, 1970; Beckman, 1972; Neufeld et al., 1980]. Therefore, when the nitrogen compound from the stripped gas liquor is removed, it is expected that these materials might act as toxic materials. Additionally, these materials not only act as inhibitors to bacteria growth but also produce foam and a bad smell through the oxidation process. So the above inhibition factors on bacteria must be considered.

Heavy metals are also known as toxic materials to bacteria. As shown in Table 2, the effluent of stripped gas liquor has very low concentration of heavy metals. Therefore, this concentration range of heavy metal has very little effect on bacteria.

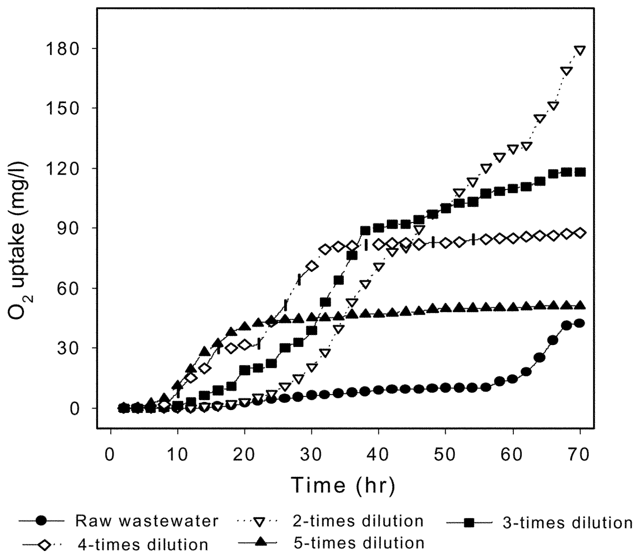

Fig. 2. Comparision of oxygen uptake for various dilution ratios of the stripped gas liquor in the respirometer experiment.

2. Effect of Dilution Rate of Stripped Gas Liquor on Nitrification Rate

In order to closely examine the nitrification rate with respect to the dilution ratio of stripped gas liquor, the bacteria respirator was used. The dilution ratios of the stripped gas liquor were 0, 2, 3, 4, and 5 times. These results are shown in Fig. 2. For raw wastewater without dilution, the oxygen up-take ratio was very slow. Also, the removal of the nitrogen compounds and BOD material without dilution was very difficult. In the case of 2 times dilution, however, the oxygen up-take ratio rapidly increased after 30 min. These phenomena imply that the higher the dilution ratio goes up, the faster the decomposition occurs. In the case of 5 times dilution, since the removal of pollutants progressed very fast, the pollutants were almost decomposed in 20 min.

Residual materials remained in the reactor after the end of the experiment. In the case of 5 times dilution sample, the concentrations of materials that caused BOD and ammonia nitrogen were 7 and 17%, respectively. On the other hand, in the case of the 2 times dilution sample, the materials that caused BOD were less than 5%, while the concentration of ammonia nitrogen only was 87% more or less. These results suggest that the lower the dilution ratio becomes, the higher the inhibited action appears. Therefore, a high concentration of organic materials and ammonia nitrogen significantly hinders nitrification efficiency because the nitrification efficiency becomes low.

It is also shown that the oxygen up-take ratio of 2 times diluted sample compared to 4 times diluted sample is mostly used to remove BOD, and the amount of oxygen up-take that is used to remove nitrogen compounds is very slight.

3. Limited Concentration of Inhibitors Influencing Nitrification at 1_{st} Batch Experiment

Through the GC, HPLC, and beaker experiment analysis, it was found that the stripped gas liquor contained inhibitor concentration similar with the concentration in the literature [Beckman, 1972; Neufeld et al., 1980]. These values are shown in Tables 3 and 4. These inhibitors are highly toxic to microorganisms. Therefore, the toxic materials such as NH_3, phenol, SCN, CN, m-cresol, toluene, quionoline, and aniline were selected to investigate the limited concentration of inhibitors that influenced the nitrification of microorganism.

4. Effect of Concentration Change of Ammonia Nitrogen on Ammonia Nitrogen Removal Efficiency

The microorganism used in the batch experiment was the same microorganism which was already applied to the above first stage.

First, after these microorganisms were washed by the diluted water, they were mixed with artificial wastewater so as to become 2,500 to 3,000 mg/*l* MLSS in 4 *l* volume reactor. The composition of artificial wastewater is shown in Table 1. To investigate the influence of ammonia nitrogen load in the first batch experiment, the initial ammonia concentration was adjusted from 100 to 800 mg/*l*, and then the change of ammonia concentration was observed every 10 hrs. As can be seen in Fig. 3, the extent of ammonia nitrogen removal was approximately a trifle amount except for ammonia concentration lower than 200 mg/*l*. But as time passed, the removal efficiency of ammonia nitrogen increased slowly.

Especially, in the reactor that had low ammonia nitrogen concentration like 100 to 200 mg/*l*, ammonia nitrogen removal efficiency was higher than 70% after 10 hrs. After 30 to 40 hrs from the beginning of the experimental operation, the ammonia nitrogen was almost removed. When the concentration of ammonia nitrogen became higher than 500 mg/*l*, the ammonia nitrogen removal efficiency was 40% under 50 hrs or more of the operation time. This suggested that high ammonia nitrogen concentration inhibits nitrifying microorganisms. Therefore, to run a safe and effective nitrification reaction requires an ammonia concentration level of 100 to 200 mg/*l* that can minimize the effect of nitrifying microorganisms.

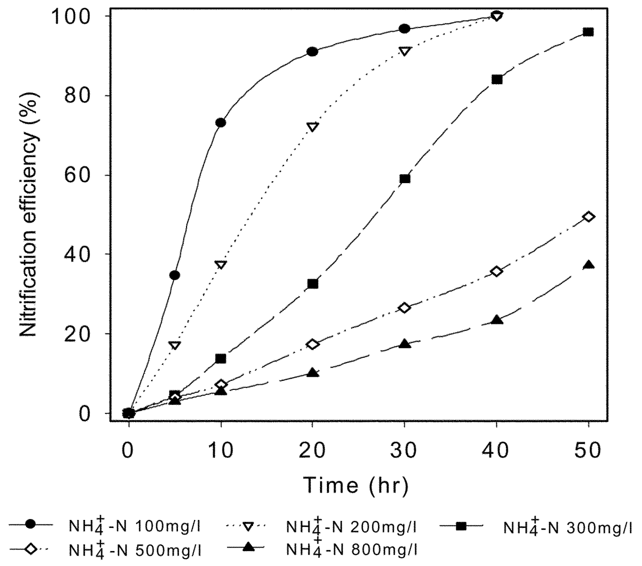

Fig. 3. Effect of NH_4^+-N load on the nitrification efficiency in the batch experiment.

5. Effect of Concentration Change of Phenol on Ammonia Nitrogen Removal Efficiency

Experimentation was carried out to discover the effect and limitation of the concentration of phenol on the removal of ammonia

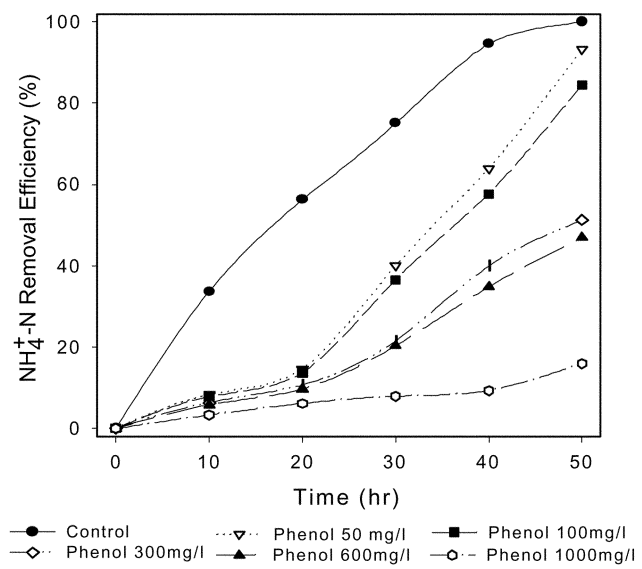

Fig. 4. Effect of phenol load on the nitirficiation efficiency in the batch experiment.

nitrogen. The extent of phenol concentration was adjusted from 50 to 1,000 mg/*l* because its concentration was similar to the concentration of the original stripped gas liquor based on the extent of phenol concentration of 500 to 700 mg/*l*.

Fig. 4 shows the removal efficiency of ammonia nitrogen related to the extent of phenol load. Five samples ranging from 50 to 100 mg/*l* and one controlled sample without phenol were used to find out the removal efficiency of ammonia nitrogen related to the extent of phenol load.

In Fig. 4, ammonia nitrogen was almost removed at 40 hrs more or less in the case of the controlled sample. On the other hand, the removal efficiency of ammonia nitrogen for the reactors that contained phenol was very low compared with the controlled sample. Even though phenol concentration was as low as 50 and 100 mg/*l*, the extent of ammonia removal was very low. In the case of phenol with 50 and 100 mg/*l*, however, ammonia removal was rapidly accomplished after 40 hrs. and the concentration became 1.4 and 2.1 mg/*l*, respectively. But when the phenol concentration was higher than 300 mg/*l*, nitrification was very slow and only 30 to 50% removal of phenol was attained after 50 hrs in reaction time. This means that a high phenol concentration has a big effect on microorganisms. Thus, not only can the nitrifier not remove phenol by itself, but also it cannot attain the completion of nitrification in a condition of highly concentrated phenol. Therefore, for effective nitrification, phenol has to be removed before being treated or should be maintained at lower than 50 mg/*l*.

6. Effect of Concentration Change of SCN on Ammonia Nitrogen Removal Efficiency

When the SCN concentration is higher than 300 mg/*l*, it is known to act as a toxic material to nitrifier [Beckman, 1972]. In order to find an SCN effect, four kinds of samples were adjusted from 100 to 900 mg/*l* and one controlled sample without SCN was used for examination.

As can be seen in Fig. 5, all four reactors that contained SCN progressed at low nitrification compared with the controlled sample. But, when the SCN concentrations were 100 and 250 mg/*l*, the efficiency of nitrification began to increase after 30 hrs operation time and complete nitrification was almost attained after 50 hrs operation time. This means that the extent of 100 and 250 mg/*l* SCN has very low effect on nitrifier and a similar result was already reported by Kim et al. [Stamoudies and Luthy, 1980]. But, if the concentration of SCN was higher than 250 mg/*l*, the effect of SCN on nitrification was highly negative. The reason that the efficiency of nitrification seldomly influences nitrifier is the increase of ammonia load due to SCN decomposition by oxidation as well as SCN itself.

7. Effect of Concentration Change of Free Cyanide on Ammonia Nitrogen Removal Efficiency

Free cyanide is known to be the most serious toxic material among the toxic materials that act on microorganisms. This study carried out the extent of concentration that is adjusted from 0.5 to 10 mg/*l* to find out the toxic effect of free cyanide on microorganism.

Fig. 6 shows that even though cyanide concentration was as low as 1 to 20 mg/*l*, nitrification almost did not occur. Therefore, it shows that cyanide highly affects nitrification of microorganism in the beginning time. The nitrification efficiency in 0.15 mg/*l* cyanide as low concentration rapidly increased after 30 hrs more or less. In the case of the concentration of 1.0 to 10 mg/*l* cyanide, the nitrification efficiency was very low, but it considerably increased after 40 hrs. Thus, the nitrification efficiency was inactive in cyanide concentration with higher than 0.5 mg/*l* because such concentration of cyanide acts as a toxic material to microorganisms.

The increase of cyanide concentration produces excessive foam and decreases the activity of microorganisms in the aeration tank. Then, it makes the operation of wastewater treatment facility difficult because it leads to the drop-off of sedimentary ability as well as sludge raising in the clarifier.

When the free cyanide concentration in stripped gas liquor is 1.5 to 2.0, the toxicity of microorganisms will be very high due to the

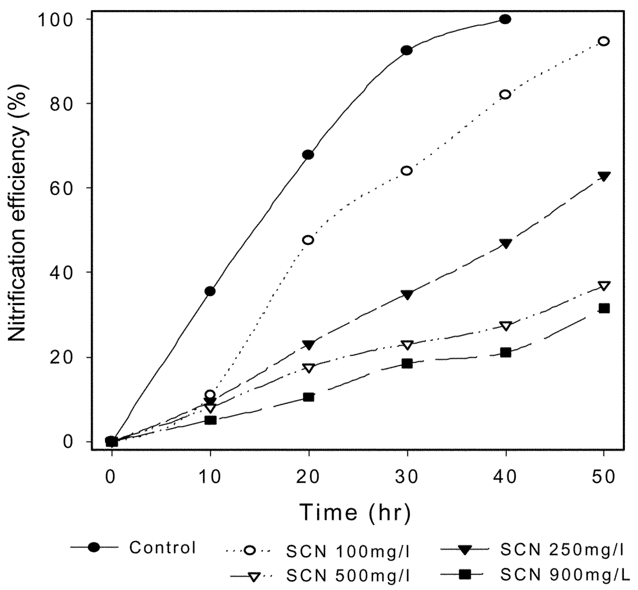

Fig. 5. Effect of SCN load on the nitrification efficiency in the batch experiment.

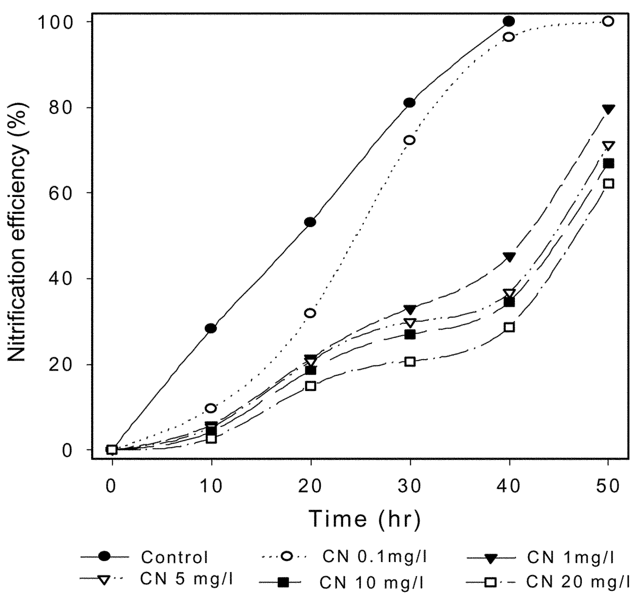

Fig. 6. Effect of CN load on the nitrification efficiency in the batch experiment.

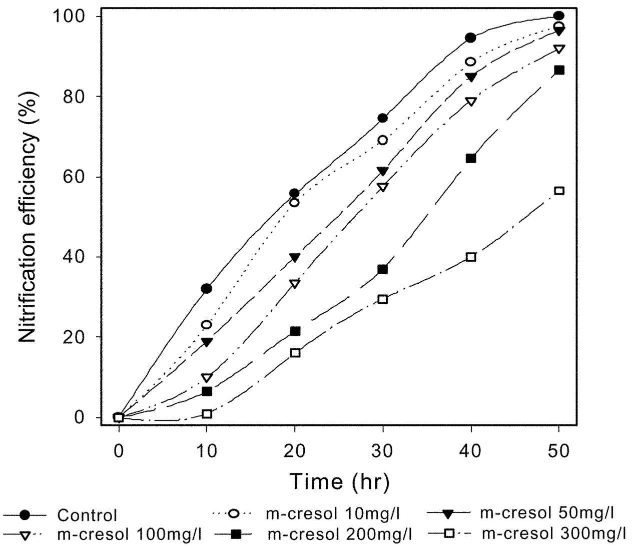

Fig. 7. Effect of m-cresol load on the nitrification efficiency in the batch experiment.

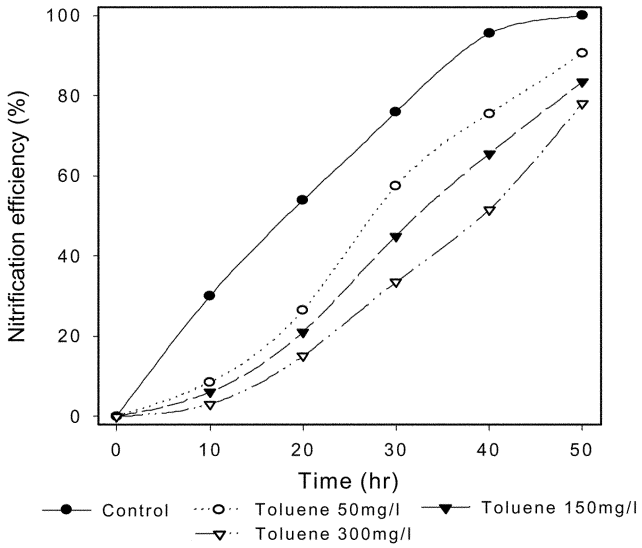

Fig. 8. Effect of toluene load on the nitrification efficiency in the batch experiment.

cyanide concentration in stripped gas liquor. Therefore, the free cyanide concentration in wastewater needs to be maintained at lower than 1.0 mg/*l* as a preceding condition.

8. Effect of Concentration Change of m-Cresol and Toluene on Ammonia Nitrogen Removal Efficiency

The m-cresol concentration in stripped gas liquor was 100 to 200 mg/*l*. Therefore, to find out the m-cresol effect on nitrification, an experiment was carried out. The range of m-cresol concentration to investigate the effect of nitrification is adjusted from 10 to 300 mg/*l*, and the results are shown in Fig. 7.

In the controlled sample similar to the previous cases, the complete removal of ammonia nitrogen occurred in 40 hrs more or less while all the samples that contained m-cresol showed a low removal efficiency of ammonia nitrogen compared to the controlled sample.

When the m-cresol concentration was 50 mg/*l*, it worked slightly as an inhibitor because the removal efficiency of ammonia nitrogen in the m-cresol concentration was similar to the control sample. But, when the m-cresol concentration was higher than 10 mg/*l*, the nitrification efficiency was highly different from the control sample. Especially, when the m-cresol concentration in stripped gas liquor was higher than 100 mg/*l*, the nitrification efficiencies after 10 and 20 hrs as initial conditions were very low. After 30 hrs more or less, the nitrification efficiencies increased and the nitrification efficiencies became 92% after 50 hrs. However, the nitrification efficiencies are generally low. Therefore, to improve the nitrification efficiencies, the m-cresol concentration must be maintained at less than 100 mg/*l*.

As shown in Table 4, the stripped gas liquor contains 85.57 mg/*l* toluene. Therefore, to investigate the toluene effect, the concentrations of samples such as control, 50, 150, and 300 mg/*l* were selected to be examined, and these results can be seen in Fig. 8. In the previous results, toluene also affected nitrification efficiency very much in the three concentration ranges. The ammonia nitrogen in the controlled sample was completely removed after 50 hrs more or less, while samples, except the controlled sample, had different ranges of ammonia nitrogen. The removal rate of ammonia nitrogen was very fast after 30 hrs more or less while the removal rate of ammonia nitrogen was very slow at the beginning time. This means that toluene significantly influences nitrifier. Even when the toluene concentration is as low as 50 mg/*l* among samples, the inhibiting phenomenon of nitrification was highly occurring compared to the control sample. Therefore, for safe nitrification, the concentration of toluene must be maintained at less than 50 mg/*l*.

9. Effect of Concentration Change of Quinoline and Aniline on Ammonia Nitrogen Removal Efficiency

In all the concentration ranges of quinoline like toluene, the nitrification efficiency was very low at the initial period. However, when the quinoline concentration was 50 and 200 mg/*l*, the removal rate of ammonia nitrogen increased rapidly after 30 hrs. As shown in Fig. 9, the nitrification rates were decreased because the inhibiting

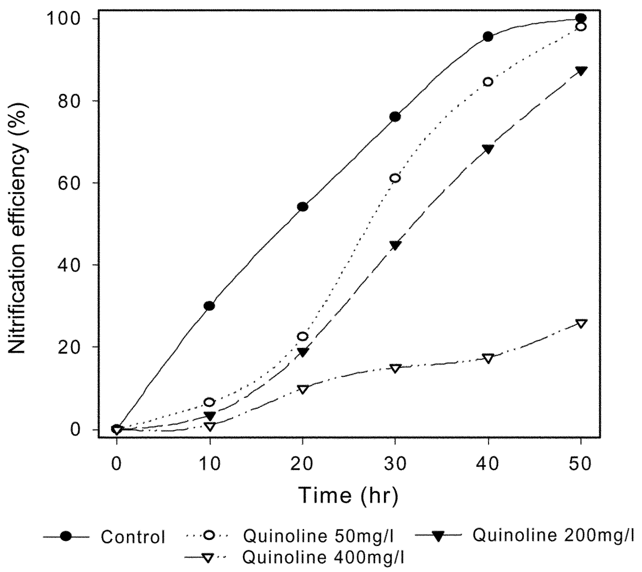

Fig. 9. Effect of quinoline load on the nitrification efficiency in the batch experiment.

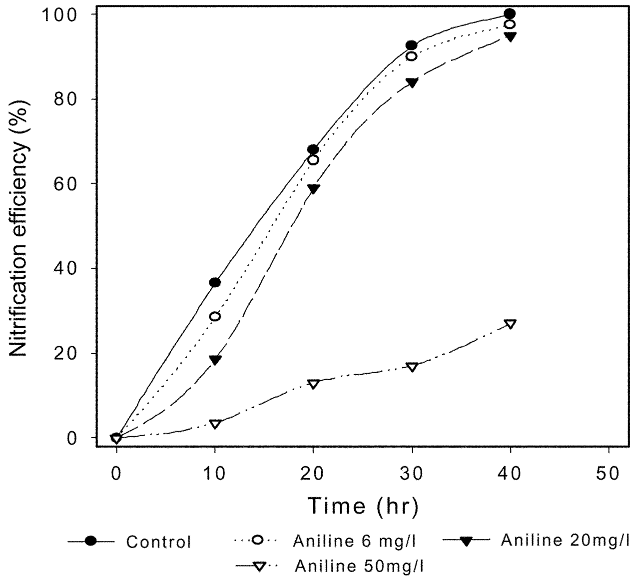

Fig. 10. Effect of aniline load on the nitrification efficiency in the batch experiment.

phenomenon of nitrification appeared in all the concentration ranges of quinoline compared with the control sample. Generally, the quinoline influence related to nitrification could be predicted as an inhibitor to microorganisms when the quinoline concentration was higher than 50 mg/*l*.

As can be seen in Fig. 10, when the aniline concentration with 6 and 20 mg/*l* was low, the aniline effects on nitrification were very small. But, in the high concentration with higher than 50 mg/*l*, the nitrification rate was very low. It is because the toxicity to microorganisms in this concentration is very high. But, it seems that the inhibited mechanism to microorganisms of aniline in raw wastewater may be very low because the aniline concentration of raw wastewater is 5 mg/*l*. Even though it depends on the adaptability of microorganism, it turns out that its concentration does not influence nitrification in the case of the concentration of aniline with 20 mg/*l* more or less.

10. Diminishing Countermeasure of Inhibitor at 2nd Batch Reactor Experiment

From the result of the first batch reactor experiment, it turns out that the materials in stripped gas liquor such as polycyclic aromatic hydrocarbon (PAH), phenol, and CN decreased the nitrification rate because these materials badly influenced nitrifiers as inhibitors. Therefore, the dilution of water and the addition of powered activated carbon (PAC) as a diminishing countermeasure of inhibitors and toxic materials in raw wastewater were carried out in the second batch reactor. Two samples were prepared such as raw wastewater and raw wastewater added with PAC. In addition, four samples which were diluted 2 and 4 times as well as added with PAC in raw wastewater were used to find out the nitrification rate. After that, each sample was added with microorganisms and analyzed for COD, ammonia, and phenol.

Fig. 11 shows the removal tendency of COD according to the dilution ratio of raw wastewater and the addition amount of PAC. The COD removal efficiency for raw wastewater and diluted wastewater was 63, 74, and 82%, respectively, after 10 days in operation. And these removal efficiencies did not show much difference between raw and diluted wastewater. It implies that the compounds in stripped gas liquor existed at a certain concentration without being decomposed by microorganism. In the reactors added with PAC, the removal efficiencies of COD were 72, 79, and 86%, respectively. These removal efficiencies of COD were high, as much as 3 to 9% compared to the reactors without PAC. Therefore, it suggests that the addition of PAC to remove COD is unnecessary.

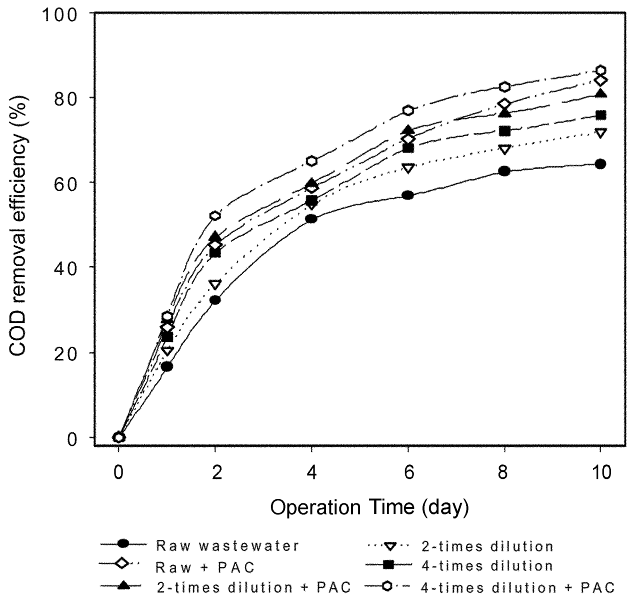

Fig. 11. COD removal efficiencies with respect to dilution ratios and PAC addition.

Fig. 12 shows the removal efficiency of ammonia according to dilution ratio of raw wastewater and the addition amount of PAC. The removal efficiency of ammonia for the samples of raw wastewater, diluted wastewater, and the samples with PAC was highly

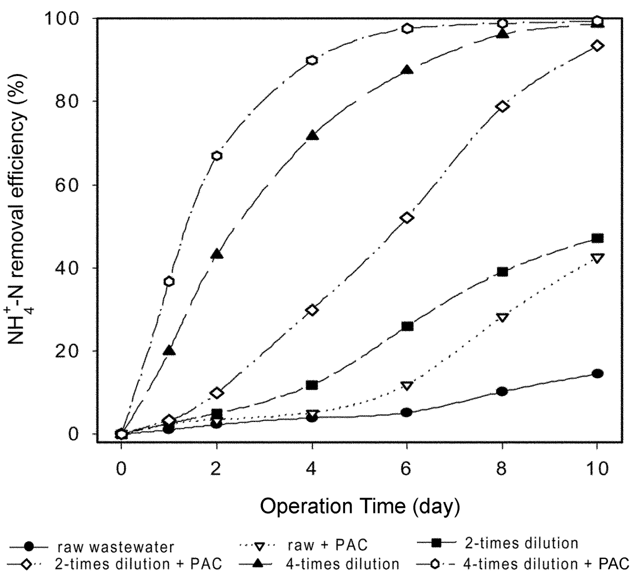

Fig. 12. NH_4^+-N removal efficiencies with respect to dilution ratios and PAC addition.

different from the cases of COD. The nitrification efficiency in the case of raw wastewater was very low, 14%, after 10 days, but the nitrification efficiency in samples which were diluted 2 and 4 times increased with the dilution ratio. Thus, the ammonia removal efficiency in these conditions rapidly increased compared with that of raw wastewater, and these were 48 and 100%, respectively. This may stem from the diminution of inhibitors and the loading of ammonia by dilution.

The ammonia removal efficiency was higher at about 29% in the samples with PAC compared to the sample of raw wastewater. But, the ammonia removal efficiency in 2 and 4 times diluted samples was 94 and 100%, respectively, after 10 days. This means that the ammonia removal efficiency was almost similar to the efficiency of samples with PAC according to raised dilution ratio of samples.

On the other hand, the ammonia removal efficiency in samples that were 2 times diluted and the sample that was diluted 2 times and was added with PAC was 48 and 94%, respectively, after 10 days. Therefore, the ammonia removal efficiency according to the addition of PAC resulted in the dilution ratio of raw wastewater decreasing from 4 times to 2 times.

CONCLUSIONS

This study was carried out to identify the impact and the threshold concentration of toxic materials on nitrification in the stripped gas liquor. Below are major results from this research.

1. The concentrations of organic materials that are contained in raw wastewater of stripped gas liquor were 400 to 600 mg/*l* phenol, 5.95 mg/*l* aniline, 17.85 mg/*l* quinoline, 197.43 mg/*l* m-cresol, 85.57 mg/*l* toluene. On the other hand, in the final effluent, 1,1-biphenyl, 6-methyl quinoline, and 2-methyl naphthalene were only detected and these concentrations were 1.56, 2.95, and 0.38 mg/*l*, respectively.

2. To find out the nitrification rate according to the dilution ratio, the dilution ratio of the stripped gas liquor was 0, 2, 3, 4, and 5 times. Removal of the nitrogen compounds and BOD material without dilution was very difficult. The higher the dilution ratio goes up, the faster the decomposition occurs. In case of 5 times dilution, since the removal of pollutants progressed very fast, the pollutants that could be decomposed were almost decomposed in 20 min.

3. The concentration of organic materials that impact nitrification of microorganisms were 200 mg/*l* ammonia nitrogen, 50 mg/*l* phenol, 1.0 mg/*l* free cyanide, 100 mg/*l* m-cresol, 50 mg/*l* toluene, 200 mg/*l* quinoline.

4. The removal tendency of COD according to dilution ratio of raw wastewater and the additional amount of PAC did not show much difference. On the other hand, the higher the dilution ratio of wastewater and the additional amount PAC goes up, the higher the removal efficiency of ammonia nitrogen increased.

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