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# Numerical Analysis of Ammonia Nitrogen Degradation in Water with Sediment

**Jianbo Pan*, Changjun Zhu**, Ming Liu** and Shijian Liu****
*North China University of Water Resources and Electric Power, Zhengzhou 450045, China
**College of Urban Construction, Hebei University of Engineering, Handan, Hebei, 056038, China

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## ABSTRACT

Based on the previous research, the experiment of ammonia nitrogen degradation in water with sediment has been set-up. The sample of sediment was selected from Zhang river. The degradation regularity of ammonia nitrogen in water with sediment was studied systematically. Under the different parameters as sediment concentration, sediment size and different initial concentrations of ammonia nitrogen, a series of experiments on the degradation of ammonia nitrogen in water with sediment were carried out. First-order kinetics was adopted to fit the experimental results, and the influences of the sediment concentration and the particle size on the reaction rate are discussed. The research shows that the degradation process of ammonia nitrogen and organisms both are conformed to the first-order kinetics and the higher the sediment concentration and smaller the particle size are, the greater is the reaction rate constant.

## INTRODUCTION

Nitrogen and phosphorus are the main nutrient elements of plants and microorganisms in water, and also the important influencing factors for aquatic ecosystems. With a lot of industrial wastewater and sewage discharge, large amounts of nitrogen and phosphorus have entered into the rivers and lakes to induce eutrophication. In natural water bodies, the migration and transformation of nitrogen and phosphorus mainly include absorbtion and release from aquatic plants. At present, the research on the concentration of phosphorus in water is on simple physical and chemical adsorption, only recently, the study on ammonia nitrogen degradation is recently paid great attention by scholars.

On phosphorus contaminant, Peng (2009) think that sediment adsorption of phosphorus in water body is similar to the role of “collect”, and the concentration of phosphorus in water decreased obviously because of the adsorption on sediment.

According to the study on sediment adsorption of phosphorus in Nanhaizi lake, Cui (2012) think that adsorption of phosphorus on sediment can be described using secondary reaction kinetics. There is competition among sediment particles in the adsorption. With the increase of sediment concentration, the adsorption of phosphorus increases, while the sediment adsorption capacity is decreased.

Hui (2009) discussed the adsorption law of suspended sediment particles on TP under the condition of the dynamic water. The results showed that when the intermittent disturbance was appeared in water, the time for adsorption and desorption equilibrium in low concentration of TP is much longer than the time in high concentration of TP. And unit sediment adsorption quantity has a linear relation with initial concentration of TP in water. Assuming sediment concentration can not change with time, the sediment adsorption will have a linear relationship with instantaneous TP concentration in water.

Ammonia nitrogen among the nitrogen pollutants has been studied by many researchers. Xia (2004) has studied the influence of particles in water on nitration, and the results showed that the particles in water accelerated the nitrification of ammonia nitrogen, and nitrification rate of ammonia nitrogen increased with the increasing of particles. In addition, Xia (2004) also studied the influence of sediment particles on the organic nitrogen transition, and found that particles can promote the transformation of organic nitrogen. More the particles in water, the faster is the rate of organic nitrogen transformation.

## DYNAMICS ANALYSIS OF DEGRADATION OF AMMONIA NITROGEN IN WATER WITH SEDIMENT

According to the Scott & Abumoghli (1995), the nitrification rate is associated with the concentration of ammonia nitrogen in water, and the degradation of ammonia nitrogen in water conforms to the first-order reaction kinetics. Huang et al. (2008)studied the degradation of pollutants in water containing sand, and concluded that the biodegradation of contaminants in water containing sand conforms to the first-order reaction kinetics. As a result, according to the dynamics analysis of the ammonia nitrogen degradation, using the first order reaction kinetics fitting, the kinetics of ammonia nitrogen degradation can be evaluated.

**First order reaction model:** For the first order reaction, the rate equation is as follows:

$$r = kc \quad ...(1)$$

$$-\frac{dc}{dt} = kc \quad ...(2)$$

Where, k is the constant of first order reaction rate.

According to integration and initial conditions, the equation can be written as:

$$\ln\frac{c_0}{c} = kt \quad ...(3)$$

The equation can be rewritten as:

$$\ln c = \ln c_0 - kt \quad ...(4)$$

or

$$c = c_0 \exp(-kt) \quad ...(5)$$

The equation 4 shows that for the first order reaction, the relationship of ln $c$ and $t$ can be drawn as a straight line.

**First order reaction of ammonia nitrogen degradation:** According to the experimental results, it was found that the logarithm of concentration of ammonia nitrogen has a good linear correlation with time $t$. Linear fitting results are shown in Figs. 1- 6.

Linear equation, $R^2$ and reaction rate constant $k$ can be obtained by ln $c$-$t$, the results are given in Tables 1 and 2.

As seen from the Tables 1-2 and Figs. 1-6, $R^2$ is over 0.93 by relative analysis of variance, which shows that the model has a good reliability and can be popularized. When the initial concentration of ammonia nitrogen is 12.11mg/L, the range of $R^2$ values is between 0.9602-0.99; and when the initial concentration of ammonia nitrogen is 8.93 mg/L , the range of $R^2$ is between 0.9318-0.9539. The research shows that the experimental data of linear fitting method accords more with that of actual measurement and the better the curve fitted, the higher is accuracy of the results.

**Effect of sediment concentration and sediment particle size on the reaction rate constant:** Experimental plot (X-axis is sediment concentration, Y-axis is reaction rate constant) is curved, which can be seen in Fig. 7.

Under the same conditions, the first order reaction rate constant ($k$) of ammonia nitrogen degradation increases with sediment concentration.

Under the conditions of the same initial concentration and sediment concentration, the smaller the particle size is, the greater the reaction rate constant is. Because the sediment particle size is smaller, the specific surface area of sediment is greater; the higher the initial concentration of ammonia nitrogen is, the greater the reaction rate constant will become, because the increasing initial concentration of ammonia nitrogen could accelerate the growth of nitrifying bacterial metabolism.

## CONCLUSIONS

According to the analysis of degradation of ammonia nitrogen under different sediment concentrations and different size criteria, the following conclusions can be drawn.

1. Sediment has some effect on adsorption of nitrogen, phosphorus and potassium permanganate index in the polluted river water. Migration of sediment with the water can play a more active role in reducing pollutant load.
2. The adsorption of pollutants on sediment in river water is influenced by many factors, such as pollutant concentration, sediment concentration and particle size. The higher level of pollutants, higher sediment content and the smaller the particle size lead to higher adsorption rate.
3. Sediment particle size also affects the rate of degradation of ammonia nitrogen in water. The smaller particle size speeds up the ammonia degradation. The smaller particle size will have larger surface area in the aqueous phase contaminants to make it easier to achieve degradation.
4. The whole process of the degradation of ammonia nitrogen is in line with the first order reaction kinetics. Under the same initial concentration of ammonia nitrogen and sediment particle size, the reaction rate constant increases with the increase of sediment concentration, and in the same initial concentration and sediment concentration of ammoniacal nitrogen, the reaction rate constant decreases with the increase of particle size.
5. Under different initial concentrations of ammonia nitrogen, the sediments increase the growth of nitrifying bacteria as compared to the clear water. The degradation reaction rate constant is large in higher initial concentration of ammonia nitrogen.

## ACKNOWLEDGMENTS

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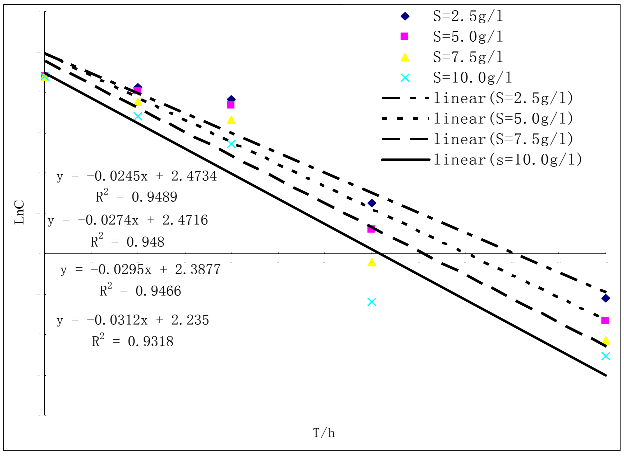


Fig. 1: Ln c-t linear fitting ($C_{0,N}$ = 8.93 mg/L, d1 ≤ 0.074 mm).

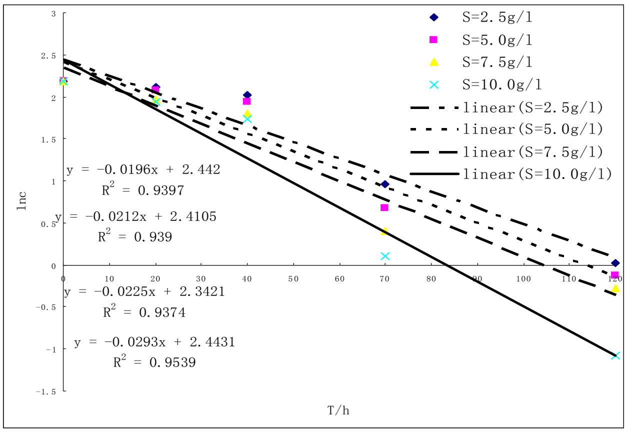


Fig. 3: Ln c-t linear fitting ($C_{0,N}$ =8.93 mg/L, 0.1 mm < d3 ≤ 0.25 mm).

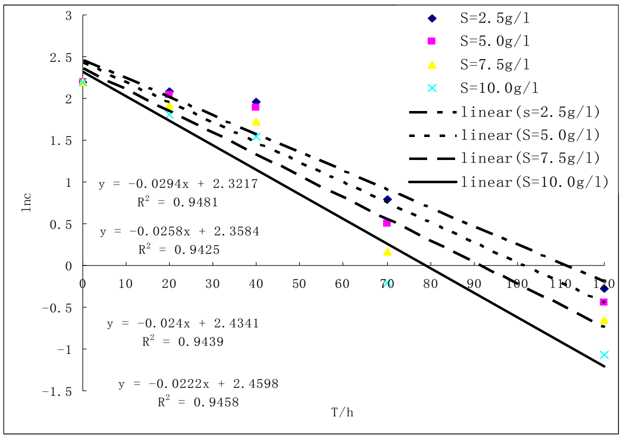


Fig. 2: Ln c-t linear fitting ($C_{0,N}$ = 8.93 mg/L, 0.074 mm < d2 ≤ 0.1 mm).

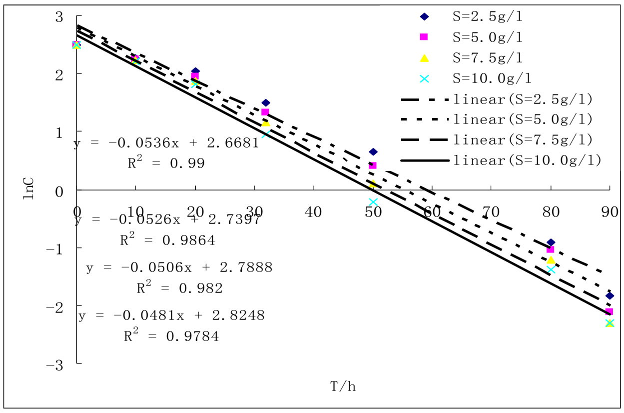


Fig. 4: Ln c-t linear fitting ($C_{0,N}$ = 12.11 mg/L,d1 ≤ 0.074 mm).

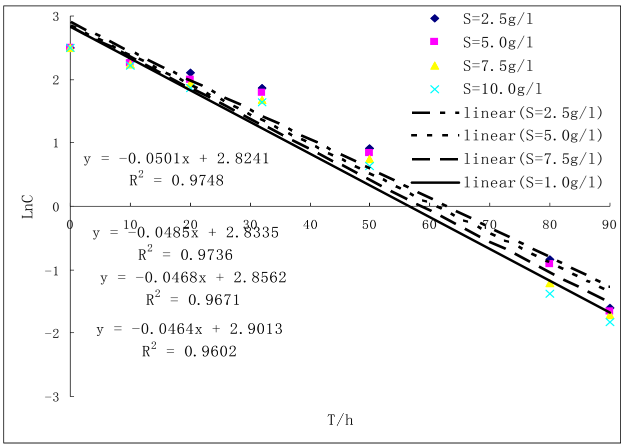


Fig. 5: Ln c-t linear fitting ($C_{0,N}$ = 12.11 mg/L, 0.074 mm <d 2 ≤ 0.1 mm).

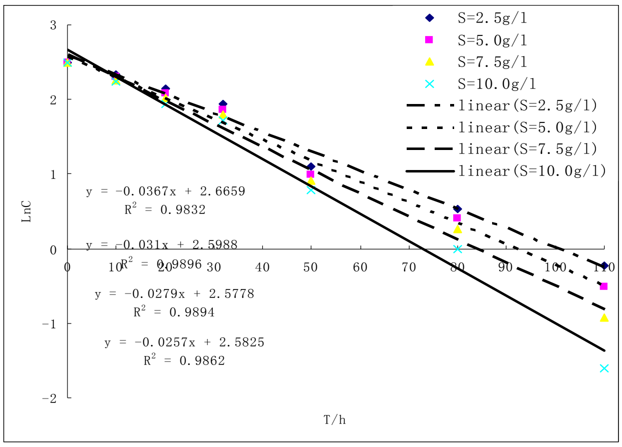


Fig. 6: Lnc-t linear fitting ($C_{0,N}$ = 12.11 mg/L, 0.1 mm <d3 ≤ 0.25 mm).

Table 1: Results of linear fitting (1).

| Initial concentration of Ammonia Nitrogen (mg/L) | The sediment particle size | Sediment concentration (kg/m$^3$) | Linear equation | $R^2$ | Reaction rate k |
|---|---|---|---|---|---|
| | d1 ≤ 0.074 mm | 2.5 | y=-0.0245+2.4734 | 0.9489 | 0.0245 |
| | | 5.0 | y=-0.027x+2.4716 | 0.9480 | 0.0274 |
| | | 7.5 | y=-0.0295x+2.3877 | 0.9466 | 0.0295 |
| | | 10.0 | y=-0.0312+2.235 | 0.9318 | 0.0312 |
| 8.93(N) | 0.074 mm < d2 ≤ 0.1 mm | 2.5 | y=-0.0222x+2.4598 | 0.9458 | 0.0222 |
| | | 5.0 | y=-0.024x+2.4341 | 0.9439 | 0.0240 |
| | | 7.5 | y=-0.0258x+2.3584 | 0.9425 | 0.0258 |
| | | 10.0 | y=-0.0294x+2.3217 | 0.9481 | 0.0294 |
| | 0.1 mm < d3 ≤ 0.25 mm | 2.5 | y=-0.0196x+2.442 | 0.9397 | 0.0196 |
| | | 5.0 | y=-0.0212x+2.4105 | 0.9390 | 0.0212 |
| | | 7.5 | y=-0.0225x+2.3421 | 0.9374 | 0.0225 |
| | | 10.0 | y=-0.0293x+2.4431 | 0.9539 | 0.0293 |

Table 2: Results of linear fitting (2).

| Initial concentration of Ammonia Nitrogen (mg/L) | The sediment particle size | Sediment concentration (kg/m$^3$) | Linear equation | $R^2$ | Reaction rate k |
|---|---|---|---|---|---|
| | d1 ≤ 0.074 mm | 2.5 | y=-0.0481+2.8248 | 0.9784 | 0.0481 |
| | | 5.0 | y=-0.0506x+2.7888 | 0.9820 | 0.0506 |
| | | 7.5 | y=-0.0526x+2.7397 | 0.9864 | 0.0526 |
| | | 10.0 | y=-0.0536+2.6681 | 0.9900 | 0.0536 |
| 12.11(N) | 0.074 mm < d2 ≤ 0.1 mm | 2.5 | y=-0.0464x+2.9013 | 0.9602 | 0.0464 |
| | | 5.0 | y=-0.0468x+2.8562 | 0.9671 | 0.0468 |
| | | 7.5 | y=-0.0485x+2.8335 | 0.9736 | 0.0485 |
| | | 10.0 | y=-0.0501x+2.8241 | 0.9748 | 0.0501 |
| | 0.1 mm < d3 ≤ 0.25 mm | 2.5 | y=-0.0257x+2.5825 | 0.9862 | 0.0257 |
| | | 5.0 | y=-0.0279x+2.5778 | 0.9894 | 0.0279 |
| | | 7.5 | y=-0.031x+2.5988 | 0.9896 | 0.0310 |
| | | 10.0 | y=-0.0367x+2.6659 | 0.9832 | 0.0367 |

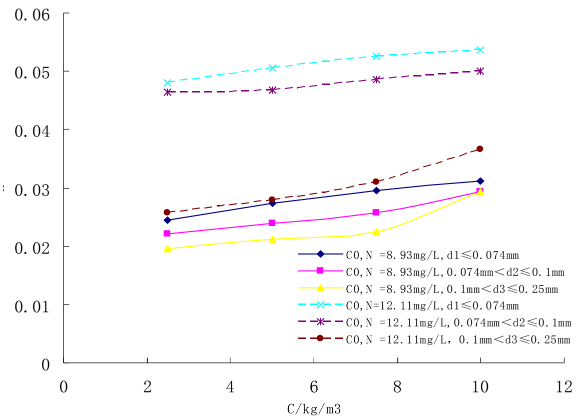


Fig. 7: Curves of the reaction rate constant changing with sediment concentration.

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