# Measuring TN and TP Degradation Coefficients With Different Treatment Enclosures at Meiliang Bay of Lake Taihu

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## Abstract

**Based on enclosure experiments, we measured time-serial total nitrogen (TN) and total phosphate (TP) concentrations at the open waters of Meiliang Bay of Lake Taihu, the enclosure with water simply isolated from the open waters, and the enclosure with macrophyte planted. The TN and TP degradation coefficients (DC) were calculated with a regression model. The TN DCs at Meiliang Bay, the enclosure without macrohyte and the enclosure with macrophytes are 0.214 $d^{-1}$, 0.153 $d^{-1}$, and 0.173 $d^{-1}$ respectively. The TP DCs are 0.305 $d^{-1}$, 0.295 $d^{-1}$, and 0.351 $d^{-1}$ respectively. Both of the TN and TP DCs are slightly greater than those in other water systems.**

## Keywords

**Total nitrogen, total phosphorus, degradation coefficient, enclosure experiment, Lake Taihu.**

## 1. Introduction

Lake Taihu, the third largest freshwater lake in China, is located in the south of the Yangtze River Delta. It is now facing with serious eutrophication problem due to the economic development in the past five decades[1]. In recent years, excessive exploitation and utilization of the surrounding environment and resources of Lake Taihu have caused a remarkable damage to the lake ecological environment, consequently, drastically making the lake water quality deteriorated. The increasing external loading from the catchment to the lake water has led to frequent and seasonal algal blooms[2-5]. So nutrients from catchment, sediment resuspension and air deposition are the key driving factors for the algal growth in this lake.

In order to know the self-purification capacity and provide substantial insight into nutrient budget in the lake, it is of great significance of studying water pollutant degradation. The self-purification capacity of a lake refers to the ability of the lake ecosystem to absorb, convert and redistribute the pollutants in the water through matter cycle in the natural state to allow the water to be self-cleaned[6]. The water self-purification is an ecological recovery way for water ecosystem[7]. Hence, to effectively control pollution and upgrade the water quality of Lake Taihu, a relatively scientific method is to develop a water quality model describing the degradation rules of nutrient elements such as nitrogen (N) and phosphorus (P), to estimate the water environmental capacity and further to control the eutrophication process.

Nutrients in natural water can be easily degraded by microorganisms. So far, a few studies have been conducted on the degradation of N and P nutrients, mostly focusing on actual application. Filippelli [8] and Edlund [9] have analyzed the adsorption and dissolving laws of N and P from sediments through

the experiment method. Liu and Zhu[10] studied the characteristics and degradation of carbon and phosphorus from aquatic macrophytes using solid-state C-13 NMR and solution P-31 NMR spectroscopy at Lake Taihu. Valdemarsen et al [11] quantified the internal nutrient loading driven by microbial mineralization of accumulated organic N (ON) and P (OP) in sediments from a shallow eutrophic estuary (Odense Fjord, Denmark).

Meiliang Bay is the most polluted area located in the north of Lake Taihu (fig.1) because it has received a lot of domestic sewage from its adjacent Wuxi city although the pollutant discharge is currently small arising from lake environmental protection actions. The bay is a very easily algae-aggregated area with prevailing winds (southeast) in summer due to its special location. So the nutrient concentrations at Meiliang Bay are always much higher than other areas of the lake caused by sewage discharge, sediment resuspension and organic matter decomposition (e.g. aggregated algae). So, it is of great significance to study nutrient cycling and further to estimate the self-purification capacity in Meiliang Bay.

This paper aims to calculate TN and TP degradation coefficients based on field experiments conducted in two different enclosures at Meiliang Bay, which are crucial parameters for calculating self-purification capacity in the whole nutrient cycling of Lake Taihu. It might be also useful for other related work.

## 2. Methodology

### 2.1 Degradation coefficient calculation

TN and TP degradation coefficients were calculated based on the first-grade reaction degradation model[12] by measuring time-serial TN and TP concentration at the same enclosure.

$$\frac{dN}{dt} = -k_N \bullet N \tag{1}$$

$$\text{That is, } N = N_0 \bullet e^{-K_N t} \tag{2}$$

where $N_0$ denotes TN or TP initial concentration, in mg/L; N denotes TN or TP concentration at t moment, in mg/L; t is reaction time, in d; KN denotes a degradation coefficient constant, in d-1. Linear equation (3) is obtained by linearizing equation (2), and solved to obtain value of KN through linear regression by the least square method. The linear equation (3) is shown as follows:

$$\ln N = -K_N \bullet t + \ln N_0 \tag{3}$$

### 2.2 Enclosure experiments

The enclosure experiments were conducted at Taihu Laborary for Lake Ecosystem Research (TLLER), located at the east coast of Meiliang Bay. The enclosures were deployed at the field experiment area of TLLER with a size of 4 m×4 m , see Fig. 1 .

There are two types of enclosure. One is “non-treatment enclosure” (NTE) with water isolated from the lake, see Fig. 2 . The other one is “duckweed enclosure” (DE) with duckweeds harvested from other macrophyte-dominated area and planted at the isolated waters. The duckweeds were planted on 24th June 2015 and the experiment was conducted after 5 months, see Fig. 3 . At the bottom of enclosure walls, the heavy lead bars were embedded in the sediment, keeping enclosure water isolated from the lake waters. So all the enclosures have the same bottom sediment with the lake. The water depth is about 2.0 m at the enclosures and the lake sampling site.

Water samples were taken at the surface (20 cm below surface), middle and bottom (20 cm above the bottom) layers at three different sites from the NTE, the DE and the adjacent lake area during 11-13 November 2015. Sampling frequency was once every three hours during the 3 days. TN and TP samples were analyzed based on conventional methods: alkaline potassium persulfate digestion method and ultraviolet spectrophotometry method[13].

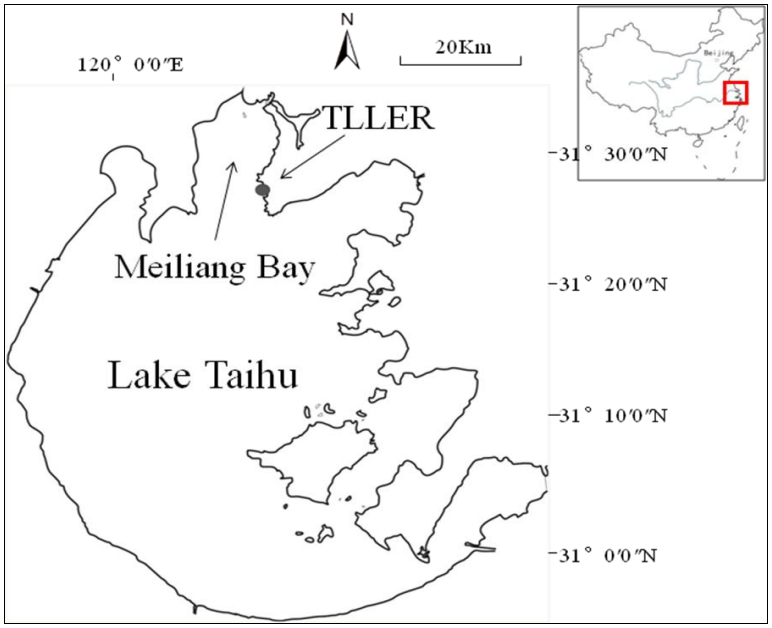


Fig.1 Lake Taihu and the Location of TLLER

Fig. 2 Non-treatment enclosure

Fig. 3 Duckweed enclosure

## 3. TN and TP DCs

### 3.1 TN and TP Initial and Final Values

Table 1 shows the initial and final values of TN and TP concentrations in NTE and DE. The initial concentrations of TN and TP at the lake water were smaller than those of NTE, DE and all of them decreased with time.

Table 1. TN and TP Initial and Final Values

| Sites | TN (mg/L) | TP (mg/L) |
|---|---|---|
| Lake water | initial: 1.61<br>final: 1.25 | initial: 0.143<br>final: 0.104 |
| NTE | initial: 3.36<br>final: 3.10 | initial: 0.259<br>final: 0.192 |
| DE | initial: 2.08<br>final: 1.54 | initial: 0.178<br>final: 0.092 |

### 3.2 TN DCs

Fig. 4 shows the TN DCs at Lake water, NTE and DE with a value of 0.214 $d^{-1}$, 0.153 $d^{-1}$, and 0.173 $d^{-1}$ respectively, which were obtained from regression based on the equation (3). The TN degradation coefficient at the lake water is the highest, then DE and NTE.

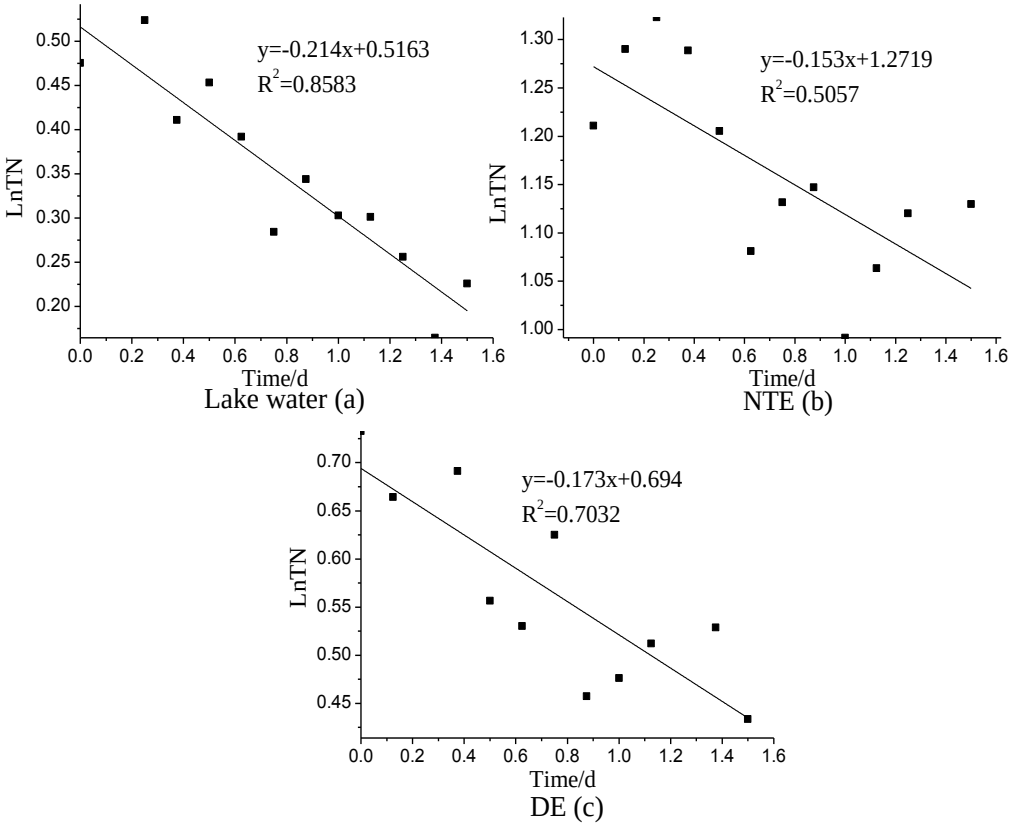


Fig. 4 TN degradation coefficients at the Lake water (a), NTE (b) and DE (c)

### 3.3 TP DCs

Fig. 5 shows the regressed TP DCs at the lake water, NTE and DE. They are 0.305 $d^{-1}$, 0.295 $d^{-1}$, and 0.351 $d^{-1}$ respectively based on the equation (3). The highest TP degradation coefficients is from DE, followed by the lake water and NTE.

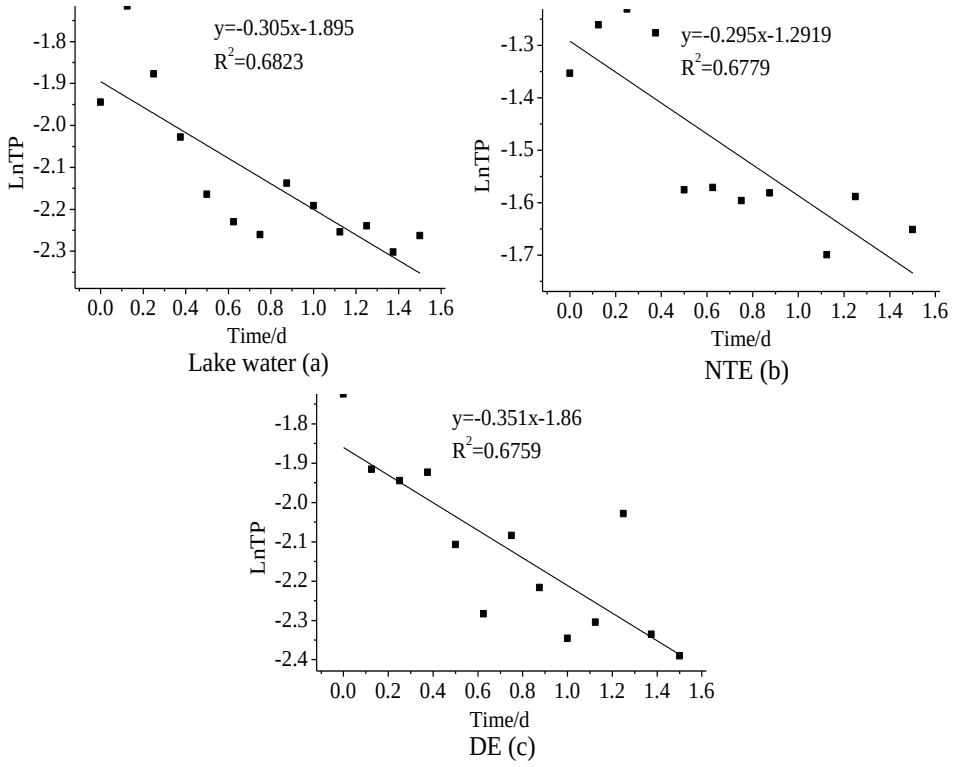


Fig. 5 TP degradation coefficients at the Lake water (a), NTE (b) and DE (c)

## 4. Discussion

The TN degradation coefficient at the lake water of Meiliang Bay is higher than that of the enclosures, which might result from the open water exchange. The TN and TP DCs at DE are both greater than those of NTE, which suggests that the duck weeds might have taken significant nitrogen and phosphorus for their growing from the enclosure water.

There have been a few studies on nutrient DCs calculation. Table 2 shows the comparison of TN and TP DCs between this experiment and other related studies. According to the literature, the TN DC is about 0.04 - 0.1 $d^{-1}$ [14] and the TP DC is about 0.13 $d^{-1}$ [15]. Obviously the TN and TP DCs in this paper are higher than those in other studies, which might be caused by the higher enrichment of nutrient-consuming organisms, microorganism activities or dramatic water-sediment exchange at Lake Taihu.

Table 2. TN and TP DCs in this paper and other studies

| Areas | TN ($d^{-1}$) | TP ($d^{-1}$) |
|---|---|---|
| Lake water of Meiliang Bay | 0.214 | 0.305 |
| NTE | 0.153 | 0.295 |
| DE | 0.173 | 0.351 |
| Xitiao River | 0.04 - 0.1 | 0.01 - 0.02 |
| Yangtze River (Yibin section) | — | 0.1308 |

There are many factors affecting TN and TP DCs including pH, dissolved oxygen, TN and TP initial concentrations, nutrient-consuming organisms, microorganism activities, nitrification and denitrification for nitrogen, hydrodynamic conditions and other-related chemical process. The comparatively higher TN and TP DCs at Lake Taihu suggest that the nutrient cycling rates are greater than the other related aquatic systems. The reason for this phenomena is currently not very clear at Lake Taihu and more studies are required to elucidate the comparatively higher TN and TP degradation coefficients in the lake.

## 5. Conclusion

(1) According to the TN and TP degradation models, TN DCs at Meiliang Bay of Lake Taihu, the NTE, and the DE are 0.214 $d^{-1}$, 0.153 $d^{-1}$, and 0.173 $d^{-1}$ respectively. The TP DCs are 0.305 $d^{-1}$, 0.295 $d^{-1}$, and 0.351 $d^{-1}$ respectively. Both of the TN and TN DCs at NTE and DE are slightly higher than those of other areas, suggesting that there might be higher nutrient cycling rates at Lake Taihu.

(2) The TP and TN DCs at DE are higher than those of NTE, suggesting that the planted macrophyes can take significant nitrogen and phosphorus from the enclosed water. So planting macrophyte might be an optional efficient method to restore the lake ecosystem.

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