Effects of a Commercial Deactivator on the Deactivation of Phosphorus in Simulated Lake Water and the Influencing Factors

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Abstract: To study the influence of external factors on the deactivator effect of a commercial deactivation under field conditions, the effects of different dosage, pH, oscillation time, oscillation frequency and initial phosphorus concentration on the deactivation effect of simulated lake water were studied. The results show that when the other conditions are the same, the deactivator has the best deactivation effect when the dosage is 0.07g, the pH is 6-9, the oscillation time of the deactivator is 45 minutes, the oscillation frequency is medium speed (180r/min), and the initial concentration of phosphorus is not more than 3mg/L. Orthogonal experiments show that the best deactivation effect is that the initial concentration of phosphorus is not more than 3mg/L, the oscillation frequency is medium speed (180r/min), and the dosage is 0.06g. The main effect of SPSS software is analyzed: the influence of initial phosphorus concentration, oscillation frequency and dosage on deactivation effect of the deactivator decreases in turn.

1. Introduction

The common problem faced by many lakes in China is Lake eutrophication, pollution sources leading to lake eutrophication include exogenous and endogenous sources [1]. After years of Lake treatment, exogenous pollution has been effectively controlled. However, the nutritional status of many lakes in China has not been effectively improved, the main reason is that the endogenous pollution of lakes has not been effectively controlled [2], it has become an important reason for the maintenance of lake nutrient phenomena. Therefore, the control of Lake endogenous pollution has become an important direction of Lake nutrient control in China [3].

Controlling endogenous pollution is mainly to control or remove nutrients from lake sediments and reduce their release to overlying water [4]. The treatment methods can be considered from two aspects: one is to inhibit the release of nutrients in sediments, such as immobilization; the other is to remove polluted sediments fundamentally, such as sediment dredging [5-6]. In-situ deactivation has great application prospects in controlling the release of endogenous nutrients, but the effect of passivated is affected by many external factors, such as wind wave, temperature, pH. [7]. Therefore, artificial preparation of simulated KH₂PO₄ solution was used to simulate lake water in this study. The effects of passivated dosage, pH, oscillation time, oscillation frequency and initial phosphorus concentration on phosphorus deactivation in lake water were analyzed by indoor analysis and test methods. The study is expected to provide reference for the improvement of deactivation and the treatment of Lake eutrophication [8].
2. Experimental materials and methods

2.1 Experimental materials and calculation methods
A commercial deactivation; potassium dihydrogen phosphate solution simulates Lake water. Based on the "Water quality—Determination of total phosphorus ammonium molybdate spectrophotometry method" (GB11893-89), the concentration of phosphate in solution was determined and the deactivation rate of phosphorus was calculated according to the following formula: 

\[ \eta = \frac{C - C_e}{C} \times 100\% \]

Where: C is the concentration of phosphorus in water before deactivation, mg/L; Ce is phosphorus concentration in passivated water, mg/L.

3. Experimental methods

3.1 Single Factor Experiment
The effects of five single variables on deactivation were analyzed, including dosage, pH, oscillation time, oscillation frequency and initial phosphorus concentration, at 25°C.

3.1.1 Deactivation dosage
Six 250ml conical flasks were added to simulated lake water with 150ml phosphorus concentration of 6 mg/L, and the pH was adjusted to 8. 0.05, 0.06, 0.07, 0.08, 0.09 and 0.10g deactivation were added to each conical flask in turn. The constant temperature water bath oscillator is adjusted to medium speed, and the setting time is 45 minutes. The effect of passivated on phosphorus in simulated lake water under different dosage was analyzed.

3.1.2 pH
Five 250ml conical bottles were added to simulated lake water with 150ml phosphorus concentration of 6 mg/L, and the pH was adjusted to 6, 7, 8, 9 and 10, respectively. 0.07g deactivation was added to each conical bottle. The constant temperature water bath oscillator is adjusted to medium speed, and the setting time is 45 minutes. The effects of deactivation on phosphorus in simulated lake water at different solution pH were analyzed.

3.1.3 Oscillation time
Six 250ml conical bottles were added to simulated lake water with phosphorus concentration of 150 ml and 6 mg/L respectively. The pH was adjusted to 8. 0.07g deactivation was added to each conical bottle. The constant temperature water bath oscillator was adjusted to medium speed, and the oscillation time of each conical bottle is set to be 15, 30, 45, 60, 75 and 90 minutes in turn. The effect of passivated on phosphorus in simulated lake water under different oscillation time is analyzed.

3.1.4 Oscillation frequency
Four 250ml conical bottles were added to simulated lake water with phosphorus concentration of 150 ml and 6 mg/L respectively. The pH was adjusted to 8. 0.07g deactivation was added to each conical bottle. The oscillation frequency of constant temperature water bath oscillator was adjusted to zero (0r/min), low (about 90r/min), medium (about 180r/min), high speed (about 270r/min) according to the rotating radian of the knob. The effects of deactivation on phosphorus in simulated lake water at different oscillation frequencies were analyzed.

3.1.5 Initial phosphorus concentration
Six 250 ml conical bottles were selected and 150ml of phosphorus was added to simulated lake water with initial concentration of 1, 2, 3, 4, 6 and 8 mg/L respectively. The pH was adjusted to 8, and 0.07g deactivation was added to each conical bottle. The constant temperature water bath oscillator is adjusted
to medium speed, and the setting time is 45 minutes. The effect of passivated on phosphorus in simulated lake water under different initial phosphorus concentration was analyzed.

3.2 Orthogonal test
The orthogonal experiment of three factors and three levels is carried out according to the single factor experiment results. Through the comprehensive analysis of the orthogonal experimental results, the optimal level combination of the experiment is obtained

| factors | Initial concentration (mg/L) | oscillation frequency (r/min) | dosage (g) |
|---------|-----------------------------|-------------------------------|------------|
|         | A                           | B                             | C          |
| 1       | 3                           | 90                            | 0.05       |
| 2       | 6                           | 180                           | 0.06       |
| 3       | 8                           | 270                           | 0.07       |

4. Results and analysis discussions

4.1 Effect of deactivation addition on phosphorus deactivation
The effect of dosage on phosphorus deactivation is shown in Fig.1:

It can be seen from Fig.1 that the four factors of controlling initial phosphorus concentration, pH, oscillation frequency and oscillation time remain unchanged. When the dosage is 0-0.07 g, the deactivation effect of the deactivation on phosphorus gradually increases with the increase of the dosage; when the dosage of the deactivation is 0.07 g, the deactivation effect reaches the best, reaching about 99%. The internal residual phosphorus concentration is 0.047 mg/L, which is less than 0.05 mg/L of Class III of<Environmental Quality Standard for Surface Water>(GB3838-2002). Therefore, when the dosage of deactivation is 0.07 g, the deactivation effect of deactivation on phosphorus in water is the best.

It can be seen from Fig.1 that when the dosage reaches 0.7g, although the deactivation effect is still slightly improved with the increase of dosage, it is not necessary to further increase the dosage to improve the deactivation effect slightly in the actual treatment process, because on the one hand, the cost of using deactivation will be greatly increased, on the other hand, more deactivation will be achieved. The use of the deactivation may increase the concentration of Al$^{3+}$ ions in water, because the deactivation formula contains Al$^{3+}$ ions, and excessive use may cause chronic toxicity of aluminum ions in aquatic organisms and reduce the diversity of aquatic organisms [9].
4.2 Effect of pH on deactivation of phosphorus

To analyze the influence of pH on deactivation effect, the paper analyzed the influence of different pH on phosphorus deactivation effect. The results are shown in Fig.2.

![Deactivation effect of different solution pH on phosphorus](image)

Fig.2 Deactivation effect of different solution pH on phosphorus

It can be seen from Figure 2 that the deactivation effect of phosphorus is significantly affected by controlling other factors unchanged. When the pH is 6-8, the deactivation effect of the deactivation increases gradually with the increase of pH; when the pH is 8, the deactivation effect reaches the best; when the pH is 8-10, the deactivation efficiency decreases with the increase of pH, and the deactivation effect decreases. Among them, when the solution pH is 6, the deactivation effect is higher than 99%, the concentration of phosphorus in solution is 0.049 mg/L, which meets the requirement of phosphorus for surface water III quality; when the solution pH is 10, the deactivation effect is less than 99%, and the concentration of phosphorus in solution is 0.067 mg/L, which exceeds the requirement of surface water III quality standard for phosphorus. In the range of solution pH from 6 to 9, the deactivation effect is further improved with the increase of pH. This is because the deactivation contains Al\(^{3+}\). With the increase of pH, the content of Al(OH)\(_3\) colloid in water increases. The larger specific surface area and electrostatic adsorption force of Al(OH)\(_3\) colloid enhance its adsorption performance for medium phosphate anion\(^{[10-11]}\). In view of the perfect deactivation effect of the deactivation in a wide range of pH\(^{[12]}\), it can completely meet the needs of natural water environment treatment under different pH conditions.

4.3 Effect of oscillation time on phosphorus deactivation

In view of the influence of water oscillation on colloidal microstructures and deactivation effect of deactivation, the effects of different oscillation time on phosphorus deactivation effect are analyzed in this paper. The results are shown in Fig.3.
It can be seen from Fig. 3 that the deactivation effect of the deactivation on phosphorus increases gradually with the increase of time when the oscillation time changes within 15-45 minutes under the control of other factors unchanged. When the oscillation time is 45 minutes, the deactivation effect of the deactivation on phosphorus reaches the best, approaching 100%, and the residual phosphorus concentration of the solution is 0.031mg/L, it can fit the requirement of phosphorus concentration for surface water Class III water environmental quality; the deactivation can still maintain the best deactivation effect within 45-60 minutes of oscillation time, which indicates that the deactivation has better anti-wind wave effect; when the time is 60-90 minutes, the deactivation effect of the deactivation on phosphorus gradually decreases with the change of time. With the prolongation of oscillation time, the colloidal microstructures are destroyed, which affects the deactivation effect [13]. Therefore, from the impact of oscillation time on deactivation effect, the deactivation is not suitable for large shallow lakes, and further improvement of its anti-wind and wave performance is still needed, such as how to improve the composition of the deactivation to increase its adsorption capacity for phosphate ions in water.

4.4 Effect of oscillating frequency on phosphorus deactivation
Because lake water disturbs sediment at different frequencies under the action of wind, which will affect the deactivation effect of deactivation, we analyzed the influence of different oscillation frequencies on phosphorus deactivation effect. The experimental results are shown in Fig.4:

![Fig. 4 Deactivation effect of different oscillation frequencies on phosphorus](image)

It can be seen from Fig.4 that the deactivation effect of the deactivation on phosphorus increases with the increase of the oscillation frequency when the oscillation frequency is controlled from 0 to 180
r/min under the same other conditions. The deactivation effect reaches the best when the oscillation frequency is 180 r/min, and the deactivation effect is close to 100%. At this time, the residual phosphorus concentration of the solution is 0.048 mg/L, which fits the requirement of surface water Class III water quality requirements; this is because the appropriate oscillation frequency is conducive to the dispersion of deactivation in water and the formation of Al(OH)$_3$ colloid, which is conducive to the improvement of deactivation effect. In practical engineering applications, the surge frequency of wind wave and underwater undercurrent caused by natural wind force will be less than this oscillation frequency [14-16]. Therefore, in general, the deactivation has better resistance to rapid disturbance of wind wave, but as the previous section analysis shows, the ability of long-term resistance to disturbance of wind wave is insufficient.

4.5 Effect of initial phosphorus concentration on deactivation of phosphorus

The initial concentration of phosphorus determines the maximum deactivation capacity of deactivation adsorption effect. Therefore, we analyzed the influence of different initial concentration of phosphorus on the deactivation effect of phosphorus. The results are shown in Fig.5.

From Fig.5, when the initial concentration of phosphorus is between 1 and 3 mg/L, the deactivation has a good deactivation effect on phosphorus, and the deactivation efficiency is over 99%. When the initial concentration of phosphorus is between 4 and 8 mg/L, the deactivation effect gradually decreases with the increase of the concentration. When the initial concentration of phosphorus is 4 mg/L, the deactivation effect in the solution decreases. The residual phosphorus concentration was 0.052 mg/L, which exceeded the requirement of surface water quality standard Class III for phosphorus concentration. Therefore, in practical engineering applications, if the concentration of phosphorus in water does not exceed 3 mg/L, the deactivation has a good deactivation effect on phosphorus, and can meet the needs of freshwater lake treatment in China [17].

To further optimize and analyze the comprehensive influence of various factors on deactivation effect, three factors and three levels orthogonal experiments were carried out. The results are shown in Table 2.

| Initial concentration (mg/L) | oscillation frequency | Dosage (g) | Deactivation effect (%) |
|-----------------------------|-----------------------|------------|------------------------|
| 3                           | low                   | 0.05       | 98.15                  |
| 3                           | middle                | 0.06       | 99.95                  |
| 3                           | high                  | 0.07       | 98.95                  |
| 6                           | low                   | 0.06       | 91.52                  |
| 6                           | middle                | 0.07       | 99.38                  |
Table 2 shows that when the initial phosphorus concentration is 3 mg/L, the oscillation frequency is medium speed (180 r/min) and the dosage of deactivation is 0.06 g, the effect of passivated on phosphorus is the best, reaching 99.95%.

To further analyze the main influencing factors, Major effect analysis is made by SPSS software. The results are shown in Table 3:

| vgh          | Square Sum of Class III | df | Square of mean value | F     | Saliency |
|--------------|-------------------------|----|----------------------|-------|----------|
| modified model | 380.271a                 | 6  | 63.378               | 4.867 | 0.18     |
| intercept    | 78727.007               | 1  | 78727.007            | 6046.105 | 0       |
| Initial phosphorus concentration | 282.987                   | 2  | 141.493              | 10.866 | 0.084    |
| oscillation frequency | 86.219                    | 2  | 43.11                | 3.311  | 0.232    |
| dosage       | 11.065                  | 2  | 5.532                | 0.425  | 0.702    |
| error        | 26.042                  | 2  | 13.021               |        |          |
| total        | 79133.32                | 9  |                      |       |          |
| total number after correction | 406.313                    | 8  |                      |       |          |

Where: $R^2 = 0.936$ (adjustment $R^2 = 0.744$)

From the significant influence factors in Table 3, the initial phosphorus concentration has the greatest influence on the deactivation effect of the deactivation, followed by the oscillation frequency, and the dosage has the smallest influence.

5. Conclusions and suggestions

5.1 Conclusion
In this paper, the effect of passivated on Phosphorus in simulated lake water was studied by changing the dosage, solution pH, oscillation time, oscillation frequency and initial phosphorus concentration. Results found:

1. When the other factors remain unchanged, the deactivation has the best deactivation effect on phosphorus when the dosage is 0.07 g, the solution pH is 6-9, the oscillation time of the deactivation is 45 min, the oscillation frequency is medium speed (180 r/min), and the initial concentration of phosphorus is not more than 3 mg/L.

2. Orthogonal experiments show that the deactivation effect is the best when the initial phosphorus concentration is not more than 3 mg/L, the oscillation frequency is medium speed (180 r/min) and the dosage is 0.06 g, reaching 99.95%.

3. According to the verification analysis of the main effect, the initial phosphorus concentration has the greatest influence on the deactivation effect of the deactivation, followed by the oscillation frequency, and the dosage has the least influence.

5.2 propose
In this paper, the influence of five factors on the deactivation effect of a commercial deactivation is analyzed under laboratory conditions. From the experimental results, it is found that the commercial
deactivation still has insufficiency in the duration of anti-wind wave oscillation. How to improve the anti-wind wave effect is the need for further improvement of the deactivation. According to relevant research, Zr\(^{2+}\), Fe\(^{3+}\) ions can improve the adsorption performance and deactivation capacity of the deactivation, so Zr\(^{2+}\) ions can be used to improve the deactivation.

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