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Biological Toxicity of Sewage Sludge Stabilized by Reed Bed on the Luminescent Bacteria

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Abstract

With the expanding scale of urban wastewater treatment, the resulting excess sludge quantity is also growing. Excess sludge treatment and disposal has become an important part of the sewage treatment. Sludge itself is rich in essential nutrients of plant growth such as nitrogen and phosphorus, so it's a good organic fertilizer; but it often also contains harmful substances such as heavy metals. If the sludge treatment is not good, it not only can bring secondary pollution to the environment, but also can cause the waste of resources. Luminescent bacteria tests are conducted in this research by comparing the effects on the absorption and transformation of toxic substances between traditional sludge drying bed and reed bed. The study finds that the biological toxicity of surface layer sludge either in reed bed or in traditional drying bed has little change with the seasons and maintains in low level. While the biological toxicity in the bottom of sludge has change with the seasons and achieves the lowest level in summer and fall, and the biological toxicity of sludge in reed bed is lower than that of traditional drying bed.

Keywords

Reed Bed, Activated Sludge, Luminous Bacteria, Biological Toxicity

1. Introduction

Now the excess sludge has become an environmental problem remaining to be solved, the recycling of the composting sludge is an effective way. However, sludge composting technology in our country is not yet fully accepted, the facilities condition is not perfect, and the successful use of the technology and the normal opera-

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tion are very few [1]. Sludge ecological stabilization is a new way to use constructed wetlands (reed bed) for excess sludge treatment [2]. The technology originates in Europe and is widely used in Denmark, Spain, America, etc. While in China and some Asian countries, this technology is in the research stage [3]-[6]. Reed bed stabilization process have the function of composting, it can make full use of plants, microorganisms, sunlight and wind to reduce the toxic substances in stabilized sludge and be transformed into fertilizer products. The ecological stabilized sludge can be used as fertilizer [3].

Luminescent bacteria method to test biological toxicity is determined by measuring the luminous intensity of luminescent bacteria and reflects the pollution situation of system. Any toxic substances that can interfere with or damage photobacterium respiration, growth, metabolism and other physiological processes can be determined through the change of the luminous intensity. Luminescent bacteria method can not only test the toxicity of water, but also test the toxicity of soil. In this paper, we use sodium chloride solution extraction for the soil sample, and then test the toxicity of extracting solution. The result can reflect the toxicity of soil sample.

Therefore, based on the stability of sludge for agricultural safety, using luminescent bacteria to measure biological toxicity of sludge in different drying conditions is necessary.

2. Experiment Part

2.1. Instrument and Reagent

The instruments and reagents include BioFix Lumi-10 biological toxicity analyzer (provide by MACHEREY-NAGEL in Germany); Freeze-dried photobacterium suite (Recovery freeze-dried luminescent bacteria; bacteria recovery liquid; osmotic pressure regulating fluid); SZCL-type 2 magnetic stirring apparatus; SHZ-D3 circulating water vacuum pump; AR124CN electronic balance; 100 - 1000 μl Flnnpipette; 2% sodium chloride solution; 0.45 μm filter paper; Special test tube; Sealed sample bag; 100 ml beaker.

2.2. Experiment Method

2.2.1. Sampling and Preservation

The test system is located in Dalian Development Zone Wastewater Treatment Plant, made by the sludge pump, the mud box and the reed bed. The traditional drying bed, ventilation reed bed and no ventilation reed bed are the same size, 3.0 m × 1.0 m × 1.3 m. System was run for two years and accumulated 15 cm sludge layer. We took stratified samplings in dried sludge by sampling apparatus. Bottom layer: 0 - 5 cm from sdiment interface; surface layer: 10 - 15 cm from sdiment interface. The samples were put in sealed bag for preservation.

2.2.2. Sample Testing

Using the balance take 10 g sample and put into 100 ml beaker, add 40 ml of 2% sodium chloride solution, stir with a magnetic stirrer for 20 minutes, then cool for 10 minutes. After that we take 10 ml clear liquid on vacuum filter. On test we take 1 ml clear liquid gently and shake to join 0.1 ml osmotic pressure regulating fluid. On the control group we take 1 ml deionized water and join 0.1 ml osmotic pressure regulating fluid. Remove the freeze-dried luminescent bacteria to join cell resuscitation liquid and add samples, then cultivate 15min in 20℃ and take the biological toxicity test.

The grade standard of luminescent bacteria biological toxicity test is listed in **Table 1**.

3. Results and Discussion

3.1. Biological Toxicity of Sludge in Different Period

Figure 1 shows the biological toxicity of sludge from traditional drying bed. The drying bed is equipped with ventilation tube, but no planting reeds. **Figure 2** shows the biological toxicity of sludge from ventilated reed bed, The reed bed is equipped with vent and planting reeds. **Figure 3** shows the biological toxicity of sludge from no ventilated reed bed, the reed bed is equipped without vent but planting reeds. **Figure 4** shows the biological toxicity of long-term natural drying sludge which consist of reed bed stabilization sludge deposit after a long time natural drying. B in figure means the surface sludge test results, D means the bottom sludge test results, C means the long time natural drying sludge test results.

Samples use luminescent bacteria to test the biological toxicity, the calculation formula is:

Table 1. Grade standard of biological toxicity.

Grade	Relative luminance (%)	Toxicity grade
I	>70	Low toxicity
II	50 - 70	Medium toxicity
III	30 - 50	Severe toxicity
IV	30 - 0	High toxicity
V	0	Highly toxicity

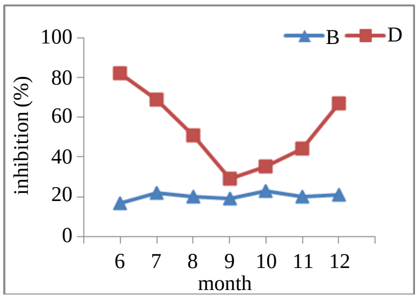

Figure 1. Inhibition rate of traditional drying bed.

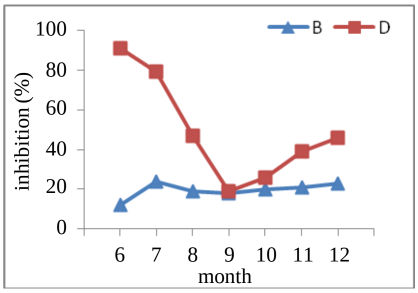

Figure 2. Inhibition rate of ventilated reed bed.

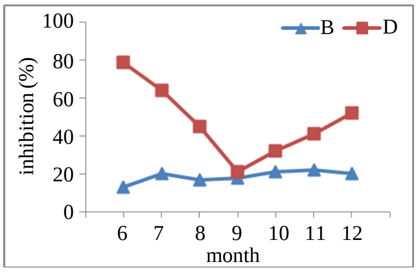

Figure 3. Inhibition rate of no ventilated reed bed.

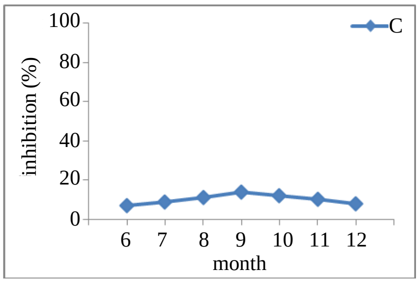

Figure 4. Inhibition rate of long-term natural drying sludge.

Sample light inhibition rate I (%): I = (R0 − R)/R0 × 100%, R0 means initial light value, R means testing light value.

Through the test results compared with the toxicity grade, we can intuitively react the toxic effect of stabilization sludge to the human body or the organism.

From **Figure 1**, **Figure 2**, **Figure 3**, we can see that in different time the biological toxicity of bottom sludge is higher than surface sludge. From **Figure 1**, **Figure 2**, **Figure 3**, the average inhibition rate of surface sludge is 20.2%, 19.5%, 18.7%, and the average inhibition rate of bottom sludge is 53.8%, 49.5%, 49.2%. According to the average inhibition rate, we can find the surface sludge almost keeps in low toxicity and has no obvious changes over time. The bottom sludge is generally in a state of medium toxicity and has big changes over time. Because the soil biological toxicity extraction liquid is sodium chloride solution, the extraction of toxic substances is water-soluble inorganic toxic substances and heavy metals. The bottom sludge through long-term accumulation causes its biological toxicity much higher.

From **Figure 1** to **Figure 3**, we can see the bottom sludge toxicity from June to September tends to decline, and from September to December tends to increase. In the beginning of spring and in summer, the bottom sludge generally presents the state of high toxic, in September it reaches minimum, as same as that of surface sludge, when time goes to winter it returns to medium toxicity even severe toxicity. This phenomenon may be due to the high temperature of summer. With temperature increasing, in sludge drying reed bed the reeds and microbial activity increases, their metabolic make the toxic substances gradually transform into non-toxic substances, greatly reduces the bioavailability and the toxicity test values. We can also find the data of D is the same as that of B in September with different conditions. This shows that through the spring and summer, the microbial metabolism makes the original accumulation of toxic substances transform into non-toxic substances.

3.2. Biological Toxicity in Different Sludge Drying Bed

Sewage purification in artificial wetland is a very complex process. It is generally believed that water, substrates, aquatic plants and microorganisms are four basic elements to construct a wetland wastewater treatment system. In the process of artificial wetland contaminant removal, the absorption, microbial metabolism, substrate adsorption, filtration, sedimentation of the plants play a key role, which includes physical, chemical and biological effect [7]-[10].

Reed bed as a kind of artificial wetland, the reed as aquatic plants can directly absorb the nutrients in sewage to grow and develop. Such organic nitrogen in waste water can be decomposed and transformed by microorganism, while inorganic nitrogen can be directly absorbed by plants to compound protein synthesis and organic nitrogen, and finally transformed into biomass, then removed from the waste water and wetland system by harvesting of plants [11]. The inorganic phosphorus is the essential nutrient of plant, and in waste water it can be absorbed by the plant and transformed into ATP, DNA, RNA and other organic compounds, then removed by harvesting of the plants [12]. At the same time aquatic plants can absorb and enrich some toxic and harmful substances, such as plumbum, cadmium, mercury, arsenic, calcium, chromium, nickel, copper, iron, manganese, zinc, etc. The capacity of absorption accumulation is submerged plant > floating vegetation > emerging plant. In different plants and different parts of the same plant, the enrichment effect is also different, in general: root > stem > foliage, and the accumulation of each organ coefficient rises and falls with concentration of sewage [13]-[15].

By analyzing from **Figure 1** to **Figure 3**, we can find the biological toxicity of surface sludge is slightly small, change is not very large.

Under different drying conditions, the biological toxicity of bottom sludge is approximately the same from season to season. From **Figure 1** we can see the bottom sludge inhibition rate changes from 82% to 29%, reducing 53% from June to September. In **Figure 2** the bottom sludge inhibition rate changes from 91% to 19%, reducing 72%. In **Figure 3** the bottom sludge inhibition rate changes from 79% to 21%, reducing 58%. From spring to summer the sludge biological toxicity in **Figure 2** decreases most quickly, next is **Figure 3**, **Figure 1** is the traditional drying bed and decreases most slowly. In September, the bottom sludge inhibition rate of **Figure 1** is 29%, **Figure 2** is 19%, **Figure 3** is 21%, all reached minimum, and the minimum value is in **Figure 2** and **Figure 3** is smaller than **Figure 1**.

The reason may be the planting reeds, in spring and summer, through its own metabolism and transformation make toxicity rate reduce more quickly than in traditional drying bed. In September, comparing the minimum value of bottom sludge we can find the toxicity of reed bed with ventilation is lower than the reed bed without ventilation. Because the ventilating pipe reed root and microorganism can get more oxygen, so we know organic matter aerobic degradation is faster than that of anaerobic condition. The degradation rate in sludge reaches the highest.

Figure 4 is a long-term natural drying sludge, we can see the inhibition rate tends to increase slightly from June to September, and slightly decrease from September to December. Changes are generally not obvious, all remain in the condition of low toxicity. By comparing **Figure 4** and **Figures 1-3**, we can find long-term natural drying process can greatly reduce the toxicity of stable sludge and can also increase the stability of stable sludge.

4. Conclusions

1) By comparing the biological toxicity of sludge in different period, we can find the biological toxicity of surface sludge has not changed much in different drying conditions, maintaining in low toxicity level. The toxicity of bottom sludge reduces from spring to summer, and increases from autumn to winter. Toxicity decreases from high toxicity to low toxicity then increases to medium toxicity or severe toxicity. The reason is that the toxicity changes with the seasons. In summer and fall, temperatures are generally on the high side, which strengthens the microbial metabolism, increases the absorption and transformation ability of the toxic substance, and reduces the biological toxicity of bottom sludge.

2) By comparing the biological toxicity in different sludge drying bed, we find the biological toxicity in reed bed is lower than in traditional drying bed, especially in summer. With temperatures rising, the metabolism of reed gradually accelerates. In summer, the respiration and absorbing ability reaches the strongest, the effects on adsorption and transformation of the toxic substances in sludge are the best. And in reed bed it can greatly reduce the toxicity of sludge. At the same time, the reed root and microbiology in dry reed bed with ventilation tube can get more oxygen and have the best effect on toxic substances degradation.

3) In the experimental cycle, the toxicity of long-term natural drying sludge gets slight increase in summer, but it still keeps in low level. It means this matter has very low toxicity or high security to the organism.

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References

[1] Liu, J. (2011) Technical Analysis on Sewage Sludge Composting and Resource Utilization Technology in Wastewater Treatment Plant. *Journal of Yangtze University*: *Natural Science Edition*, **8**, 246-248.

[2] Sun, H.J., Cui, Y.B., Wang, F., *et al*. (2011) Comparison of Residual Sludge Dewatering and Stabilization between Reed Beds and conventional Sludge Drying Bed. *Journal of Safety and Environment*, **11**, 81-84.

[3] Nielsen, S. and Willoughby, N. (2005) Sludge Treatment and Drying Reed Beds Systems in Denmark. *Water and Environmental Journal*, **19**, 296-305. http://dx.doi.org/10.1111/j.1747-6593.2005.tb00566.x

[4] Uggetti, E., Ferrer, I., Molist, J. and García, J. (2011) Technical, Economic and Environmental Assessment of Sludge Treatment Wetlands. *Water Research*, **45**, 573-582. http://dx.doi.org/10.1016/j.watres.2010.09.019

[5] Tefanakis, A.I., Akratos, C.S., Melidis, P. and Tsihrintzis, V.A. (2009) Surplus Activated Sludge Dewatering in Pilot-Scale Sludge Drying Reed Beds. *Journal of Hazardous Materials*, **172**, 1122-1130. http://dx.doi.org/10.1016/j.jhazmat.2009.07.105

[6] Cui, Y.B., Sun, H.J., Yang, M.L. and Liu, Y.H. (2012) Plant Growth for Sewage Sludge Ecological Stabilization. *Journal of Residuals Science &Technology*, **9**, 47-53.

[7] Song, Z.W., Wan, R.Q., Xi, J.X., Han, X.Y. and Yao, C. (2005) Nitrogen and Phosphorous Removal Efficiency and Dynamic Feature of Constructed Wetlands for Sewage Treatment. *Chinese Journal of Ecology*, **24**, 648-651.

[8] Sun, Q., Zheng, Z. and Zhou, T. (2001) The Procedure of Wastewater Treatment for Constructed Wetland. *Pollution Control Technology*, **14**, 20-23.

[9] Yu, S.-P., Sun, G.-Y. and Dou, S.-Z. (2004) Treatment Technology of Wastewater Using Constructed Wetland and Its Application in Dongping Lake. *Wetland Science*, **2**, 228-233.

[10] Vacca, G., Wand, H., Nikolausz, M., Kuschk, P. and Kästner, M. (2005) Effect of Plants and Filter Materials on Bacteria

Removal in Pilot Scale Constructed Wetlands. *Water Research*, **39**, 1361-1373.
http://dx.doi.org/10.1016/j.watres.2005.01.005

[11] Sun, G.Z., Zhao, Y.Q. and Allen, S. (2005) Enhanced Removal of Organic Matter and Ammoniacal-Nitrogen in a Column Experiment of Tidal Flow Constructed Wetland System. *Journal of Biotechnology*, **115**, 189-197.
http://dx.doi.org/10.1016/j.jbiotec.2004.08.009

[12] Seo, D.C., Cho, J.S., Lee, H.J. and Heo, J.S. (2005) Phosphorus Retention Capacity of Filter Media Forest Imating the Longevity of Constructed Wetland. *Water Research*, **39**, 2445-2 457.

[13] Cheng, S.P., Grosse, W., Karrenbrock, F. and Thoennessen, M. (2002) Efficiency of Constructed Wetlands in Decontamination of Water Polluted by Heavy Metals. *Ecological Engineering*, **18**, 317-325.
http://dx.doi.org/10.1016/S0925-8574(01)00091-X

[14] Jin, G., Kelley, T., Vargas, N. and Callahan, M. (2003) Preliminary Evaluation of Metals Removal in Three Pilot-Scale Constructed Wetland Systems. *Management of Environmental Quality*: *An International Journal*, **14**, 323- 332.
http://dx.doi.org/10.1108/14777830310479414

[15] Wu, J.Q., Ruan, X.H., Wang, X. (2005) Selection and Function of Aquatic Plants in Constructed Wetlands. *Water Resources Protection*, **21**, 1-6.