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# Study and analysis of biodegradability and degradation rate of mineral lubricating oil

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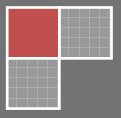
## ABSTRACT

Mineral oil is one extracted from mineral that cannot be degraded by general microorganism which means it has poor biodegradability. Some of mineral oils are poisonous, so they may bring harms into environment. Given that shortcomings of mineral oil, now several well-known lubricating oil manufacturers are studying how to make use of vegetable oil and compound ester to produce lubricating oil. However, owning to cheapness and good anti-friction of mineral lubricating oil, they are still sold in market. So it is a big issue in the study of raw material of lubricating oil that how to improve biodegradability of mineral oil. This study focuses on a biodegradation accelerant made from long-chain fatty acid and amino acid which can improve the degradability of mineral oil and proves effective and stable property through experiments. Through the copper corrosion test and rust-proof property test, the non-corrodibility and rust-proof property of this accelerant are tested. The mineral oil HVI 350 is used in this study and in which mixing a certain amount of glycine can compare the changes of property of mineral lubricating oil before and after the mixing. And conclusion is that: biodegradation accelerant developed by the study can effectively accelerate the degradation of mineral lubricating oil.

## KEYWORDS

Mineral lubricating oil; Biodegradability of lubricating oil; Biodegradation accelerant; Degradation rate.





## INTRODUCTION

Lubricating oil made from mineral oil occupies a lot in the market. But because the biodegradability of lubricating oil is so low that will bring harms to environments. The solutions now are used widely in sectors such as building, industry, energy, environmental protection, etc. In order to meet the water quality requirements for discharge or reuse of waste water, in this research, sewage treatment focuses on industrial wastewater. The theories of biodegradability are mainly of physical method, chemical method, physical-chemical method and biological method. And the biological method is used mostly. But the wastewater treatment process is complex, so only one method cannot meet the requirements of biodegradability and the process will also add physical method and chemical method together. So improving the biodegradability of mineral lubricating oil has great importance to reducing pollution produced by mineral lubricating oil and development of environmentally friendly lubricating oil.

According to the research on environmental microbiology, some compound can accelerate the reproduce of microorganism, enhance the microbial activity and improve the biodegradation of degradation-resistant compound which is also called anaerobic and aerobiotic technology. A refers to the anaerobic part; O refers to the aerobiotic part. This technology is based on the first one which wipes out organics from sewage and effectively wipes out nitrogen and phosphorus. Compare to the technology of activated sludge, it remarkably improve the availability of biodegradation accelerant. This is called technology of adsorption biodegradation which has high energy-saving benefit for industrial sewage treatment in high concentration and high applicability. But this approach focuses on bioflocculation in high load, so it will produce more sludge. Dealing with reactants in high load would increase the cost of sewage treatment. This study creates a biodegradation accelerant made from long-chain fatty acid and amino acid which can improve the degradability of mineral oil which proves effectiveness through the experiments.

## EXPERIMENT

### Materials of experiment

Lauro-acyl glycine(L－Gly for short): is made in laboratory and its structural formula is CH3(CH2)10CONHCH2COOH; The sample of soil: takes soil 0～20 cm from earth surface with cored sampling apparatus, after blending, edulcoration and sieving（1 mm）, which will put into sample bag;
HVI 350 mineral lubricating oil: are provided by ESSO.

### Experiment of biodegradation of lubricating oil

Divide sample of soil into two groups. In this system, differential pressure instrumentation should be installed in the pipeline of unit. When instrument gives out the signal of high differential pressure, the system will immediately start the process of biodegradation accelerant and will automatically start the technology of backwashing which can ensure that water-filtration could go safely. At the same time, with the help of PLC control site, the connection signal of external unit of reception unit is received. And once the control site reveals the unusual signal, the system will immediately stop and prepare for the inspection, which enhanced the system reliability. Respectively sample the 0, 2, 5, 10, 15, 20 sample of soil and adopt the gravimetric method to measure the residual of lubricating oil[15] in the sample. The process is: accurately weigh and take 10g soil from the sample and put them in the conical flask with grinding plug; add into 50 mL CHCl3 and gently shake the flask 1～2min; the classification of two-dimension quality cannot change, while basic quality property may transfer into the undifferentiated quality as the change of time and environment. And this questionnaire forward direction $5^{th}$ coefficient x are: tangibility coefficient is 0.85; reliability coefficient is 0.82 ; responsiveness coefficient is 0.74 ; indemnificatory coefficient is 0.66 ; according to the table, the input and output counts are 18 and 16, so the thesis chooses the CPU224 programmable logic controller from Siemens S7- 200 which has 22 input count and 18 output count. In order to make PLC goes well, digital quantity extended module EM223 from the same Siemens series is adopted.

After the PLC, it is necessary to choose the differential pressure instrumentation. In the sewage disposal system, it is essential to install differential pressure instrumentation otherwise the controlling of filtration of water is not effective. When the filtration goes wrong, it is not quick to find the problem and solve it and possibly the instrument will be destroyed. The reason is not difficult to understand which is mentioned above. When the entrance and exit of the differential pressure are too high, it is necessary to stop the filtration of water. Without the instrument, the differential pressure cannot be shown, and the filtration of water will not stop. The empathizing coefficient is 0.80; the gross coefficient is 0.86. According to the concentration formula (1)of residual lubricating oil from soil sample, count the biodegradation rateε：

$$\varepsilon = \frac{S_0 - S_t}{S_0} \times 100\% \quad \textbf{(1)}$$

S0 refers to the mass fraction （mg·g-1） of lubricating oil from the soil sample in 0 day, St refers to one in t day.

## RESULT AND CONCLUSION

### Biodegradability of lubricating oil

TABLE 1 shows the changes of biodegradation rate of lubricating oil from two groups' soil sample. After adding L-Gly into HVI 350, the rate increases remarkably, showing that L-Gly can improve the biodegradability of lubricating oil.

**TABLE 1 : Changes of biodegradation rate of lubricating oil with time**

| Time t/d | The First Group (HVI 350) | | The Second Group (HVI 350+L-Gly) | |
|---|---|---|---|---|
| | $S_t$/(mg.g$^{-1}$) | $\varepsilon$ /% | $S_t$/(mg.g$^{-1}$) | $\varepsilon$ /% |
| 0 | 50.4 | | 51.6 | |
| 2 | 49.1 | 2.58 | 47.0 | 8.91 |
| 5 | 47.9 | 4.96 | 43.8 | 15.12 |
| 10 | 44.6 | 11.51 | 38.7 | 25.00 |
| 15 | 41.2 | 18.25 | 35.2 | 31.78 |
| 20 | 37.2 | 26.19 | 31.3 | 39.34 |

### Model of biodegradability of lubricating oil

According to summarizing research of model, the model of rate fit the biodegradation of organics[16-17], the relation between degradation rate and matrix mass fraction is shown :

$$-\frac{dS}{dt} = kS^n \quad \textbf{(2)}$$

S is matrix mass fraction; k is disappearance rate constant; n is reaction order. The integral forms of zero-order reaction （n=0）,first-order reaction（n=1）and second-order reaction(n=2）, are shown in form（1）:

$$n=0: \quad S_t - S_0 = -kt \quad \textbf{(3)}$$

$$n=1: \quad \ln(\frac{S_t}{S_0}) = -kt \quad \textbf{(4)}$$

$$n=2: \quad \frac{1}{S_t} - \frac{1}{S_0} = kt \quad \textbf{(5)}$$

S0 is start matrix mass fraction; St is one of moment t. In different environment, there are different reaction orders. Mentioned above, if two units need enter backwashing, the first one is priority, because the functional diagram shows that the second unit delays 0.1 second. But if one unit enters backwashing, the other should wait. Because they have an interlocking function.

Finally, it is essential to pay attention to fault diagnosis subroutine. During the subroutine accelerant, as for software, the external device may possibly fail whose main function is outputting signal. If the fault cannot be solved immediately, the system may go wrong and may be destroyed. So it is necessary to design a subroutine of fault diagnosis to ensure the system will stop and raise the alarm. This study designs eight subroutines of fault diagnosis which have similar fault diagnosis algorithms. In the filtration of water, the inlet valve and the outlet valve are not open, magnetic filter is not power on, blow-down valve or compressed air valve are open, the system goes wrong and raises the alarm and halt to wait for inspection. According to the relation between matrix mass fraction S and time t, form (3), form (4) and form(5), fit the degradation rate equation.

Equation fitting of rate

Assuming that the reaction rate of biodegradation of lubricating oil similarly follow first order reaction rule, biodegradation rate equation is form (4). TABLE 2 shows the changes of mass fraction and $\ln\left(\frac{S_t}{S_0}\right)$ of lubricating oil from two groups' sample.

**TABLE 2 : The relation between mass fraction of lubricating oil and time**

| Time t/d | the first group (HVI 350) | | the second group (HVI 350+L-Gly) | |
|---|---|---|---|---|
| | $S_t$/(mg.g$^{-1}$) | $\varepsilon$ /% | $S_t$/(mg.g$^{-1}$) | $\varepsilon$ /% |
| 0 | 50.4 | | 51.6 | |
| 2 | 49.1 | -0.0261 | 47.0 | -0.0934 |
| 5 | 47.9 | -0.0.0509 | 43.8 | -0.1639 |
| 10 | 44.6 | -1.1223 | 38.7 | -0.2877 |
| 15 | 41.2 | -0.0.16 | 35.2 | -0.3825 |
| 20 | 37.2 | -0.3037 | 31.3 | -0.4999 |

According to the results of experiments, $\ln\left(\frac{S_t}{S_0}\right)$ and t is conducted by linear regression from two groups of samples and the results are shown in the Figure 1 and Figure 2.

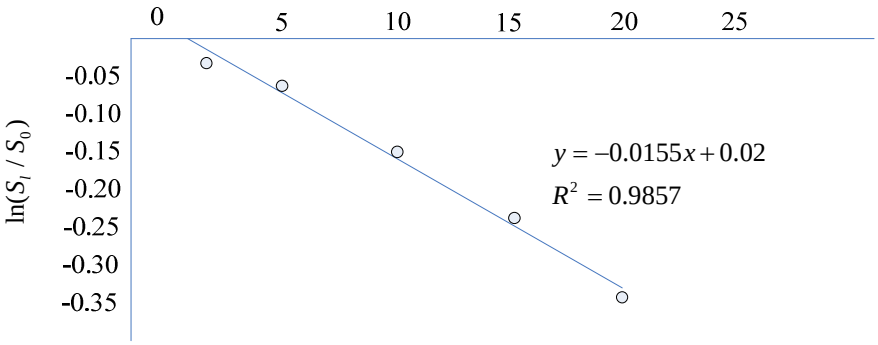



**Figure 1 : Fitting graph HVI 350 of degradation kinetics**

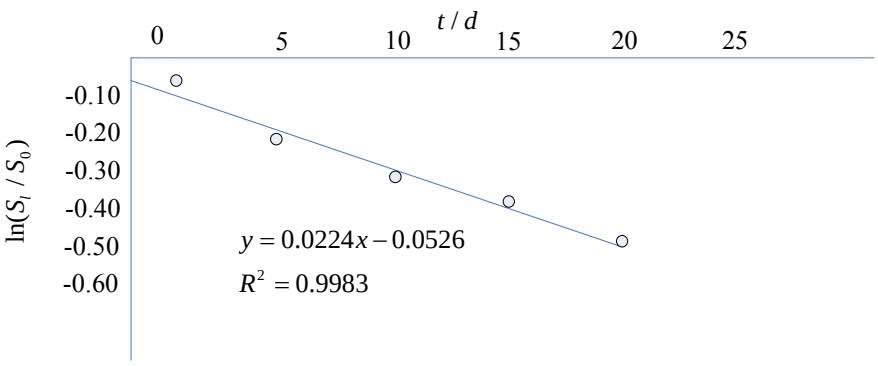



**Figure 2 : Fitting graph HVI 350 + L-Gly of degradation kinetics**

In the fitting graph, slope of $\ln\left(\frac{S_t}{S_0}\right)$ and t is the reaction rate constant k. The reaction rate constant of HVI 350 mineral lubricating oil（the first group sample） k =-0.0155 mg·g-1·d-1, degradation rate equation is $\ln\left(\frac{S_t}{S_0}\right) = -0.0155t$ ,and $S_t = 50.4e^{-0.0155t}$ ; the reaction rate constant of HVI 350 mineral lubricating oil added L-Gly（the second group sample） k=-0.022 4 mg·g-1·d-1, degradation rate equation is $\ln\left(\frac{S_t}{S_0}\right) = -0.0224t$ , and $S_t = 51.6e^{-0.0224t}$ .

In this study, regression test of rate equation is adopted to evaluation system for degradation reaction rate of mineral lubricating oil. And the property of indicator mainly reflects the degree of students' attention. According to the conclusion above, the first work is to improve the basic property: the degradation has been introduced in the early semester that the course outline helps students with different methods; the correct skills of degradation reaction are learned by students.

Students take it for granted. Facing these properties will not increase the satisfaction of quality of teaching; lacking these properties will reduce the satisfaction of degradation of mineral lubricating oil.

Besides, it is essential to improve the property of charm: for instance this method facilitates the degradation of mineral lubricating oil; lacking tends to dissatisfaction. After receiving of the survey, analyze them with the general correlation method and T test method which both have reached the general the level of significance ($P<0.05$). And in the end, all questions are remained for later analysis. Firstly, assuming that each component instrument and the gross instrument were considered as Cronbach's coefficient. When reliability $x>0.7$, the reliability is really high; when $0.35<x<0.7$, the reliability is ordinary; when $x< 0.35$, the reliability is low. This survey's forward direction questions five layer x coefficients are: the tangibility coefficient is 0.85 ; reliability coefficient is 0.82 ; Responsiveness coefficient is 0.74; indemnificatory coefficient is 0.66; empathizing coefficient is 0.80; the gross coefficient is 0.86. So improving the property of expectation is not only start from the site facility but teacher's care about students. The result of dispatch is shown in TABLE 2.

From TABLE 2, it is essential to improve expectation property: for instance the degradation reaction environment; quantity and quality of quantity using in the experiment and degradation property of mineral lubricating oil; patterns and contents of degradation are immediately adjusted; the software questions of degradation of mineral lubricating oil are solved immediately. And students think that lacking of these properties lead to dissatisfaction. So improving the property of expectation is not only starts from the site facility but teaching skills about degradation of mineral lubricating oil. In this study, there are 23 quality properties in which the basic ones are 9, accounting for 39.1%; quality properties of charm are 5, accounting for 21.7%. That is to say those students have positive judgment of degradation of mineral lubricating oil, and the improving work can start from basic quality properties to expectation property and the property of charm is considered as a long-term work. The classification of two-dimension quality may be changed and the previous basic quality property will change into undifferentiated one as time and environment. According to the research results of client's thoughts, the property of charm will become the expectation quality after a while and gradually become into a basic quality. This rule shows that the progressive and difficult-to-satisfy of students' demands. So as for the same survey, it is necessary to do the tracking survey which is a only way to meet the demand of degradation of mineral lubricating oil so as to get 95% satisfaction of students. Use F test respectively carry out the significance test the regression model of rate equation of sample from two groups, and fitting precision of regression equation are tested are shown in the TABLE 3.

**TABLE 3 : The results of regression model test**

| regression equation | F test value | F criticality test value | multiple correlation coefficient R | multiple correlation coefficient square $R^2$ | revise multiple correlation coefficient square Adj $R^2$) |
|---|---|---|---|---|---|
| $S_t = 50.4e^{-0.0155t}$ | 206.518 | 10.128 | 0.9928 | 0.9857 | 0.9809 |
| $S_t = 51.6e^{-0.0244t}$ | 1807.176 | 10.128 | 0.9991 | 0.9983 | 0.9978 |

From TABLE 3, F test value is bigger than criticality test value which means that dynamical model of two groups of sample is suited to the relation between St－t; The test can reach the level of significance ($P<0.06$), and the total correlation also achieves the level of significance ($P<0.07$), finally keeps these questions for the later analysis. Firstly, assuming that checking each component chart and gross chart were Cronbach's coefficient. When $x>0.9$, it means that reliability is really high; when $0.36<x<0.9$, it means that reliability is general; when $x< 0.32$, the reliability is low.

## CONCLUSION

This study focuses on biodegradation accelerant made from long-chain fatty acid and amino acid which can increase degradability of mineral oil. Through the experiments, the accelerant proves to be efficient and stable. Through the copper corrosion test and rust-proof property test, the non-corrodibility and rust-proof property of this accelerant are tested. The mineral oil HVI 350 is used in this study and in which mixing a certain amount of glycine can compare the changes of property of mineral lubricating oil before and after the mixing. And conclusion is that: biodegradation accelerant developed by the study can effectively accelerate the degradation of mineral lubricating oil.

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