Asynchronous Cultivation and Domestication of Aerobic Activated Sludge to Treat the Pickle Wastewater

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Abstract: The domestication of activated sludge which was from domestic sewage treatment plant was studied, the effects of the pre acclimated sludge and acclimated sludge on the pickle wastewater were investigated, and the effects of pH, HRT (hydraulic retention time), aeration intensity, dissolved oxygen DO and other factors on the removal efficiency of COD were studied during the continuous operation of acclimated sludge. Experimental results show, the domesticated sludge which has been domesticated for 28 days has a stronger ability to adapt and deal with the sludge before acclimation. Under the condition of continuous water inlet and outlet, pH = 7, aeration intensity of 1000ml / (min. L), temperature of 17 ℃, HRT = 4h, the removal rates of COD, NH₃-N and TP were 93%, 36% and above, respectively, the effluent concentrations were 88, 1.27 and 1.17mg/L respectively, and the removal load of COD was about 1.38kgCOD/ (m³.d).

1. Introduction
There are two main types of pickle wastewater: salty wastewater and desalinated water at the finishing stage. Compared to high-salt saline wastewater, the pickle cleaning wastewater lowers salinity, which mostly belonged to the low-salt wastewater. Pickle cleaning wastewater contains a large amount of organic matter, nitrogen and phosphorus nutrients, etc. If the direct discharge without treatment can cause eutrophication, the high salinity of kimchi wastewater discharged directly into the soil will cause severe salinization of the soil. [1-2], because of its weak acidity and high organic content can easily produce the bad smell and breeding mosquitoes and flies. High salt saline wastewater containing high salinity, fewer emissions, and some row once a year, and some two or three years before discharge once, and can be re-used. Aerobic treatment is less biodegradable, domesticated sludge for a long time. However, the amount of water used for cleaning wastewater is large, production must be accompanied by emissions, and the water quality has seasonally varied with different season and types of pickled vegetables. Compared with the treatment of salty high salt wastewater, the treatment of low salinity wastewater is more water, uncontrollable water quality and timeliness of treatment. Therefore, it is very necessary to remove the pollutants from pickle wastewater and reduce or even eliminate the threat of pickle wastewater to water pollution. The research object of this paper is the desalinated water after coagulation treatment.

Currently, the treatment of food waste mainly biological methods, adsorption, oxidation, etc. [3-8]. Activated sludge method as a kind of biological method has been more than one hundred years old. With its continuous development, it has become the main way to deal with organic wastewater. [5] and [9].
The traditional activated sludge method research on pickle wastewater is mostly high salt saline wastewater, while less research on low salt cleaning wastewater. After coagulation and adsorption, the biodegradability of cleaning wastewater is well, COD concentration is reduced to 1000-2000mg /L, in order to achieve the further reduction, this paper attempts to direct the aerobic biological treatment of the coagulated pickle cleaning wastewater. This paper is divided into aerobic sludge acclimation and aerobic biological treatment of two stages. Coagulation has a certain effect on the removal of COD, but the concentration of NaCl remains at the level of 4-6g/L. The presence of salt in the wastewater can destroy the microbial cell membrane and the enzyme in the cell body, which can inhibit the growth of the microorganism [9-11], thus increasing the difficulty of biological treatment of salt-containing wastewater, so domestication of activated sludge is the first step. After domestication of microorganisms in the salt-containing environment, it can adapt to the corresponding salinity environment by the adjusting metabolism [11]. After the sludge acclimation is mature and stable, it enters the aerobic biological treatment stage. By analyzing the effects of pH, nutrients, dissolved oxygen, aeration intensity and water retention time on the effect of aerobic biological treatment, the optimum operating conditions of aerobic treatment are determined.

2 Experimental Materials and Methods

2.1 Experimental materials
Wastewater: The experimental pickle wastewater was taken from Xinfan Food Co., Ltd. The raw wastewater was the cleaned wastewater after the salted vegetables. In this paper, waste water after coagulation is studied. It is light yellow with low turbidity and good transparency. The wastewater the main indicators in table 1.

Table 1 Quality indexes of pickle wastewater

| Item                | Content            |
|---------------------|--------------------|
| COD/(mg/L)          | 1000~2000          |
| pH                  | 5.5~6.5            |
| Turbidity           | 10~30              |
| Salt content/(g/L)  | 4~6                |
| SS/(mg/L)           | 50~200             |
| Total nitrogen      | 40~60              |
| NH3-N/(mg/L)        | 2~5                |
| Total phosphorus    | 2~5                |

Aerobic sludge: The sludge is taken from the aeration tank of the High and New Zone sewage treatment plant, and the indexes of the sludge are in the normal range. The concentration of MLSS is 4427mg/L, the concentration of MLVSS is 3088mg/L, and SV30 is 22.2%.

2.2 Experimental reagents, equipment and devices

2.2.1 Experimental reagents and equipment.
The main equipment and reagents in the experiment are shown in table 2.
Table 2  Main reagents and equipment

| Device name                      | Model    | Manufacturer                                      | Major reagents          | Major reagents          |
|----------------------------------|----------|---------------------------------------------------|-------------------------|-------------------------|
| Mute adjustable oxygen pump      | SB-948   | Zhongshan City Song Bao Electric Appliance Co., Ltd. | Glucose                 | Mercuric sulfate        |
| Dissolved oxygen tester          | JPBJ-608 | Shanghai Instrument Electric Science Instrument Co., Ltd. | Ammonium acetate        | Ammonium ferrous sulfate |
| Electronic balance               | BS-124-S | --                                                | Dipotassium phosphate   | Potassium sodium tartrate |
| Vacuum suction device            | --       | --                                                | Sodium hydroxide        | Potassium iodide        |
| Microwave digestion device       | WXJ-III  | Qingdao Hong Hai environmental protection equipment Co., Ltd. | Concentrated sulfuric acid | Ammonium chloride       |
| Visible spectrophotometer        | 722s     | Shanghai Precision Scientific Instruments Co., Ltd. | Silver sulfate          | Antimony potassium tartrate |
| Hand-held pressure steam sterilizer) | JSM280G-18 | Ningbo jiuxing Medical Equipment Co., Ltd. | Potassium dichromate    | Ascorbic acid           |

2.2.2 Experimental device

![Figure 1. Experimental device diagram](image)

2.3 Experimental method

Acclimation of aerobic activated sludge: Domesticated and domesticated by asynchronous training and intermittent water exchange. It will be taken from the sewage treatment plant aeration tank sludge mixture into the laboratory simulation aeration tank, first, under the condition of aeration intensity 800ml/min.L, the mixture was exposed for 2 days. After dormant microorganisms were activated and the use of glucose, ammonium acetate and potassium phosphate dibasic nutrients dubbed CODcr: N: P = 150: 5: 1 culture medium for domestication. According to the operation of the traditional activated sludge process, the CODcr of the mixture is around 450mg/L, the supernatant is changed with the nutrient solution, and the water is changed every 3 days. The aeration time is 18h/d in 3 days before the start of the operation, and the aeration is 8h every day in the next two weeks, so as to restore the activity of the sludge. Since then, reduce the amount of water in the nutrient solution, and gradually increase the amount of wastewater after coagulation treatment. According to the coagulation treatment of pickle wastewater 20%, 40%, 60%, 80%, 100%, each water distribution conditions stabilize for 2 days, change water twice daily and continue aeration until the water is completely replaced by the coagulated wastewater. The MLSS, MLVSS, SV30 and other indicators of activated sludge were measured every
two days to understand the performance of activated sludge. When all indicators of sludge were stable under the condition of full water distribution and the treatment effect was stable, it was concluded that the acclimation of activated sludge was completed.

Aerobic experimental process: Continuous domesticated activated sludge system has been domesticated water, continuous aeration, continuous effluent. Though the adjusting the water inlet speed to control the hydraulic retention time, adjust the influent pH with NaOH solution, adjust the aeration intensity to control the dissolved oxygen, measure the effluent COD concentration every 2h to test the aerobic treatment effect, measure MLSS, MLVSS, SV30 and other indicators to detect sludge growth and proper artificial sludge. Analysis of various factors (hydraulic retention time, pH, aeration intensity, dissolved oxygen, etc.) on the removal efficiency of COD to determine the best conditions for system operation in order to achieve a stable flow of water.

3. Aerobic activated sludge domestication

3.1 Aerobic sludge domestication process

Acclimation process, the control inlet pH is 7, the aeration intensity is 800ml/ (min.L), the residence time is 12h, and the inlet temperature is the same as the ambient temperature, which is 15-20 °C. The water intake was 20%, 40%, 60%, 80%, 100% after coagulation treatment, and each water distribution condition was stable for 2 days. The water was changed twice a day and continued to be aerated until the water were completely replaced by the coagulated wastewater until the sludge and effluent were steadily domesticated and the whole process of domestication lasted 28d. Due to the rapid growth of sludge during the domestication, exploratory sludge was carried out on the eighth day. Changes in the indicators during domestication in figure 2.

As can be seen from figure 2, during the acclimation process, COD removal rate has been maintained at a high level. In the pre-domesticated stage, due to the continuous increase of chloride ions COD removal rate showed slight fluctuations because of activated sludge in salinity wastewater. Under the impact of the temporary break the original metabolic balance of flora, so that the sewage treatment capacity fluctuations, but the microorganisms through their own metabolism regulation, and soon be able to adapt to the corresponding salinity environment, starting from the first 16 days of sludge Item index reached a stable, the final COD removal rate remained at 94%. Microbial use of wastewater nutrients maintained a high growth rate. From the 8th day onward, due to the abrupt decrease of microbial concentration in the system due to exploratory mud discharge, the original influent COD concentration was still maintained, which increased the organic load of the sludge in the system. Under the impact of this organic load, a consequent increase in the viscous expansion of the sludge results in a sudden increase in SV30. In the continuous training, with the stable water distribution conditions, the sludge volume adjustment, the system gradually stabilized, the domestication of aerobic sludge completed 28 days. MLSS concentration of domesticated sludge was kept at about 4000mg / L, MLVSS concentration was maintained at 3000mg / L, sedimentation ratio (SV30) of sludge was maintained at about 35% and COD removal rate was maintained above 94%.
3.2 Mature sludge in the biological phase

Observed under a biological electron microscope domesticated mature sludge species of protists, bacteria loose mass group as shown in figure 3. It can be seen from the observation results that the primary organisms in the sludge are mainly ciliated parasites, among which there are triticum sp, campanulaceae pestis, all kinds of trumpet worms and a few swimming ciliates. Micro-metazoans have a few rotifers. The opening of the thrips is more constricted, probably because of the variability of the thrips in salinized environments [11], which shows a better adaptability to the experimental wastewater environment. It can be seen from the figure that the micelles are loose and small, with a light yellowish brown color. These protozoa and micro-metazoan both play an instructive role in biological processes. The presence of a large number of anchovies and rotifer indicates the water quality is good, also shows that domesticated more mature, and the sludge on the experimental wastewater has a better ability to adapt and handle.

3.3 Acclimation before and after the comparison of sludge indicators

Before taming, the sludge is yellow brown and the floc with soil odor. With the process of domestication, the color of the sludge becomes shallow and the floc becomes small. Finally, it becomes yellowish brown, slightly sour, and the floc is fine and fine. In the early stage of full influent, a large number of white foams appeared, and disappeared in fourth days.

Before domestication, MLSS concentration was 4427mg/L, MLVSS concentration was 3088mg/L, SV30 was 22.2%, MLSS concentration was 4158mg/L, MLVSS concentration was 3040mg/L, SV30 was about 35%. By taking three batches of water, the removal of COD in the raw water at different residence time in different residence time was investigated in chronological order. The control of water pH was 7, the temperature was about 17℃, and the aeration amount was 800ml/ (min.L). See figure 4 before domestication, and see figure 5. after domestication.

![Figure 4](https://example.com/figure4.png)  
**Figure 4.** Removal of COD before sludge acclimation

![Figure 5](https://example.com/figure5.png)  
**Figure 5.** Removal of COD after acclimation of sludg

It can be seen from figure 4 that as time goes by and the amount of treated wastewater increases, the effect of the treatment becomes worse and worse. The first batch of water, HRT = 5h, COD removal rate can reach 90%; the second batch of water, HRT = 9h, the COD removal efficiency to achieve the best and removal rate of 88.6%; the third batch of water when HRT = 9h, the COD removal efficiency tends to be stable and the removal rate is 85.7%. As can be seen from figure 5, for the same acclimated sludge sample, the removal rate of COD can all reach more than 90% and both stabilize at HRT = 4h. In summary, the acclimated sludge has more stable and efficient processing capacity. The reason is that under the impact of salinity wastewater, the imbalance of the original microflora makes the sewage treatment capacity of the sludge decrease. The microbial population in the sludge after domestication has gradually formed the enzyme system to metabolize the salt wastewater through its own metabolism, thus having the specificity of treating the salt containing wastewater to make the treatment effect stable and efficient.
4. Aerobic experimental process

4.1 Aeration on the dissolved oxygen and COD removal rate

Control of influent COD is 1412mg/L, pH is 7, the temperature is about 17 °C, and the residence time is 6h. The removal of COD by sludge under different aeration conditions is investigated.

![Figure 6. Effect of aeration on dissolved oxygen and COD removal rate](image)

As can be seen from figure 6, within a certain range, with the increase of aeration, the dissolved oxygen concentration and COD removal rate in water show the trend of first increasing and then decreasing. When the aeration rate is 1000 ml/(min. L), the COD removal rate is the highest, which is 91%, the dissolved oxygen concentration is 6.8mg/L at this time. When the aeration rate is 1200 mL/(min. L) oxygen concentration reached the maximum, 6.93mg/L, COD removal rate is 88.7%. Due to the lower temperature, the amount of dissolved oxygen in water is relatively large. The aeration is small because of lack of oxygen poor performance led to poor performance of activated sludge. By aeration, while maintaining the dissolved oxygen concentration between 0-6.8mg/L, the COD removal rate of wastewater also increases with the increase of dissolved oxygen. However, the aeration rate continues to increase. Dissolved oxygen not only does not increase but decreases due to the analytic effect, but sludge is not easy to form flocs and the structure is loose due to the turbulent flow caused by aeration [14-15]. At the same time, the efficiency and power consumption factors were comprehensively combined to determine the optimum aeration rate of aerobic wastewater treatment was 1000 ml/(min. L).

![Figure 7. Effect of residence time on the removal of COD, NH3-N and TP](image)

4.2 Residence time on the removal of pollutants

Controlling the influent pH to 7, the temperature to about 17 °C and the aeration rate to 1000mL/(min. L), two batches of water were selected for experiments, which were 1# raw water and 2# raw water respectively. The removal of COD, NH3-N and TP by sludge at different residence time was investigated, as shown in figure 7.

As can be seen from figure 9, COD, NH3-N and TP removal rates are also increasing with the increase of residence time. COD and TP almost simultaneously reduced, the concentration dropped sharply within 0-1h, and then slowly decreased to 4h is no change in the gentle; the concentration of NH3-N has been a slow decline in the trend. At HRT = 4h, the removal rates of COD, NH3-N and TP reached 93%, 36% and 85%, respectively, and the concentrations were 88, 1.27 and 1.17 mg/L, respectively. Taken together, determine the residence time of waste water 4h, effluent COD of 88mg/L or less, COD removal load of 1.38kgCOD/(m³.d).

5. Conclusion

(1) The aerobic activated sludge of domestic sewage treatment plant is domesticated by asynchronous training and intermittent water exchange. the sludge can be stably matured after 28 days. The acclimated mature sludge has a light yellowish brown color with slight sourness, The floc was fine sand but the precipitation performance was good. MLSS concentration was kept at about 4000mg/L, MLVSS
concentration was maintained at 3000mg/L, SV30 was maintained at 35% and COD removal rate was maintained at 94%.

(2) Wastewater is directly treated with activated sludge from domestic sewage treatment plant. The COD removal rate continues to decrease with the increase of treated water volume, while the COD removal rate of acclimated mature sludge can be kept stable at above 90%. The microbes in the sludge were mainly attached ciliates and bell worms, indicating that the acclimated activated sludge had stronger adaptability and processing ability than before domestication.

(3) Under the conditions of pH = 7, aeration intensity of 1000mL/(min. L), temperature of 17 ℃ and HRT = 4h, the removal rates of COD, NH3-N and TP reached 93% 36% and 85%, respectively. The effluent concentrations were 88, 1.27 and 1.17 mg/L, respectively. The COD removal load was 1.38 kgCOD/(m³.d).

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