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RESEARCH ON THE INFLUENCES OF INSULATION TECHNOLOGY BY PLASTIC GREENHOUSES ON WORKING TEMPERATURE IN AERATION TANKS IN COLD AREAS IN WINTER

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ABSTRACT

According to the problem of low temperature in cold regions and low working temperature in aeration tanks in sewage works, by means of the simulation to analyze the distribution and flowing features of air and temperature in greenhouses, the heat preservation technology in the greenhouses of wastewater works will be researched under the condition of low temperature in winter in cold regions. Results show that under the condition of - 22 ℃ outdoors in winter, through the insulation of the canopy towards the aeration tank, the average air temperature remains 4 ℃ or so, while the water temperature of the outlet of the aeration tank remains about 11.2 ℃; The material of insulation membrane of the outside aeration tank which is the most optimal is to be PO, while the most undesirable material is PVC, and PE and EVA mediate; The aeration tank which has the best heat preservation is the one that uses greenhouses with 2.5 meters high; The effect of double insulation membranes is better than that of single membrane.

Keywords: cold regions; greenhouse; aeration tank; working temperature.

1. INTRODUCTION

It is severely cold in winter and this period is very long in Northeast China. The sewage works run their businesses in low temperature for long time, and there is a great fluctuation in inflow load, which leads to lower effective biomass and worse biological metabolic activity. So it is difficult to run stably in sewage treatment. It deteriorates the water quality, especially makes nitrogen, phosphorus and organic matter exceed a certain limit. In addition, the physicochemical and biochemical functions reduced significantly because of the influence of low temperature, and it's difficult to effectively remove contaminants through the traditional process. The efficiency of the sewage works decreases, which affects the water security in the tributary and the trunk stream.

Scholars at home and abroad had done a lot of theoretical and experimental researches on strengthening the sewage treatment technology [1-2]. Developed countries in cold regions such as North America and Nordic Europe had advanced pollution-control technology and management experience. The control technology was the most common method that enhanced the sewage point source to reduce water pollution in winter [3-4].

P. Gostelow and other experts studied the influence of sharp temperature drop on nitrification efficiency and investigated whether the ideal effect of nitrification could be achieved by dosing domesticated nitrifying bacteria below 20 ℃ through sequencing batch reactor activated sludge process reactor(SBR) under the condition of 10℃ [5]. D. Gang studied the influence of temperature on the release and absorption mechanism of biological phosphorus removal reactor in such continuous flow activated sludge treatment systems from 5℃ to 20. The ability to store polyphosphate isolated was detected at different temperatures [6].

The researches on the prevention and cure towards water pollution at low-temperature periods mainly concentrated on research institutions of the Northeast China. There were mainly two aspects to improve the running efficiency of sewage treatment works at low temperature. On the one hand, the traditional process was improved. The anaerobic and anoxic period were added in order to strengthen the nitrogen and phosphorus removal. On the other hand, the key packing with the appropriate proportion was added to the biochemical pool in order to form a complex biological treatment system. The appropriate living environment of the anaerobic and anoxic aerobic bacteria was created in the original pool so the removal of nitrogen and phosphorus was enhanced. A.X. Jiang and other researchers in Harbin Industrial University isolated psychrotrophs with the ability of degrading organic pollutants in sewage, and adopted composite flora of cold tolerance to treat low temperature sewage [7]. J. Yin et al. conducted an experiment on the test of soil humus enhanced SBR's operation efficiency [8, 9]. M. Wu et al. studied the measures to improve activated sludge's settling and dewatering performance [10].

The research on the effect of sewage treatment in cold regions has been made, but there is no research on the use of the insulation of greenhouses to improve the working temperature in aeration tanks in winter. Based on the research above, the characteristics of water quality in sewage works under the condition of low temperature in cold regions of the northeast in winter were studied. Through the simulation analysis [11], the heat transfer mechanism and characteristics of the distribution and flow of air and temperature inside the winter greenhouses were analyzed. The reasonable shapes of greenhouses, space, size, material, etc. were determined, and the influences of insulation on the working temperature in aeration tanks in cold regions were pointed out.

2. FUNDAMENTAL FORMULATION AND MATHEMATICAL DESCRIPTION

In order to make the simulation results accord with the fact as much as possible as well as guide the practical engineering to some extent, the parameters needed in the model's setting and calculating process are supposed to refer to the real engineering data as much as possible [12].

The problem considered, as shown in Figure 1, refers to the 3-dimensional flow and heat transfer in a greenhouse with solar radiation. The aeration tank located at the bottom and was created by pouring concrete. The sewage flows through the aeration tank. The plastic greenhouse covered the aeration tank, whose length, breadth and height is L, B, and H respectively. The air is filled above the sewage surface. The inlet temperature of sewage is Ti and the outlet temperature of sewage is to. The solar radiation intensity is q.

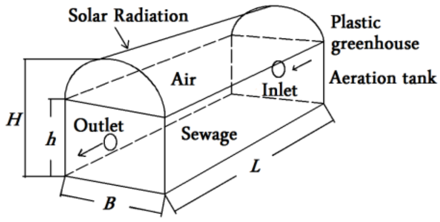


Figure 1. Geometry of greenhouse

The governing equations for the conservation of mass, momentum and energy are expressed as follows [13-18].

Equation of continuity:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad (1)$$

Momentum equation:

$$\frac{\partial u}{d\tau}=\frac{\partial u}{\partial \tau}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=F_x-\frac{\partial p}{\rho\partial x} \qquad (2)$$

$$\frac{\partial v}{d\tau}=\frac{\partial v}{\partial \tau}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=F_y-\frac{\partial p}{\rho\partial y} \qquad (3)$$

$$\frac{\partial w}{d\tau}=\frac{\partial w}{\partial \tau}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=F_z-\frac{\partial p}{\rho\partial z} \qquad (4)$$

Energy equation:

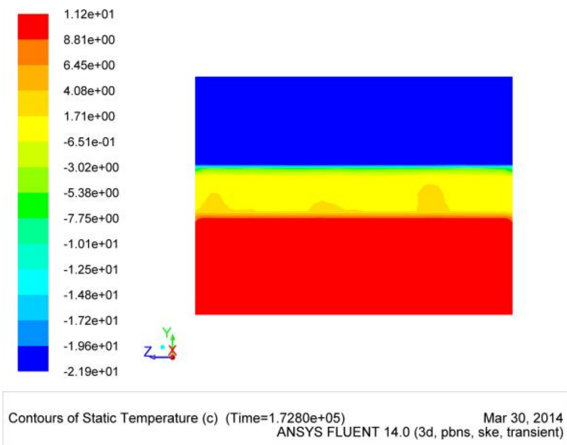
$$\frac{\partial^2 t}{\partial x^2}+\frac{\partial^2 t}{\partial y^2}+\frac{\partial^2 t}{\partial z^2}=0 \qquad (5)$$

Using Fluent for simulation calculation, the basic way is finite volume method[19]. Convection diffusion can be dispersed with QUICK differential treatment.

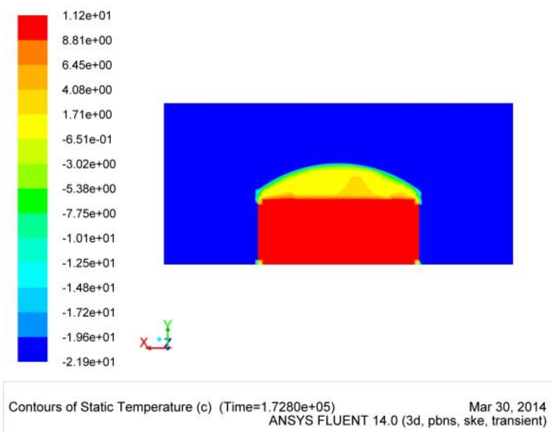
3. RESULTS AND DISCUSSION

3.1 The distribution of temperature in the greenhouse

In this paper, the material of the greenhouse is PO. When the environment temperature is -22℃ in winter, the inlet temperature of the aeration tank is 10 ℃ with solar radiation. The temperature distribution in the single-membrane greenhouse is shown as Figure 2.



(a) The temperature field at $X=L_x/2$



(b) The temperature field at $Z=L_z/2$

Figure 2. Temperature field in greenhouse

It can be seen in Figure 2 that the temperature distribution in the greenhouse changes when the plastic greenhouse covers the aeration tank. The temperature of air near the film is lower, and the temperature of air far away from the film is higher. The temperature distribution of sewage is almost the same because of the large velocity of sewage.

The temperature field in the greenhouse and average temperature of sewage are monitored in this paper. The experiment results show that the average temperature of the air in the greenhouse is about 4.0℃ and that of the outlet of sewage is 11.1℃when the environment temperature is -22℃. The simulation results show that the average temperature of the air in the greenhouse is about 4.0℃ and that of the outlet of sewage is 11.2℃when the environment temperature is -22 ℃. The experiment results are consistent with the simulation ones. The temperature is close to the effective working temperature of the aeration tank. Obviously, the greenhouse insulation plays a good role in the effective operation of the sewage treatment.

3.2 The influence of material on insulation effect

When the greenhouse materials are PO, PE, EVA and PVC respectively, the average temperature of air in the greenhouse and the average temperature of outlet sewage are monitored for 144 hours in this paper. The changes of the average temperature and that of the outlet sewage are described in Figure 3 and Figure 4. The influence of solar radiation on the temperature of air in the greenhouse and the temperature of the outlet sewage is analyzed when different materials are used.

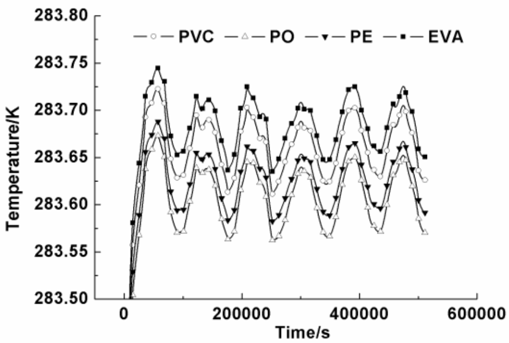


Figure 3. Temperature of sewage

As shown in Figure 3, the temperature fluctuations of the outlet sewage are all 0.1K when the greenhouse materials are PO, PE, EVA and PVC respectively. The temperature of the outlet sewage varies from 283.65K to 283.75K when EVA is used. The temperature of the outlet sewage varies from 283.57K to 283.67K when PO is used. The difference is not obvious.

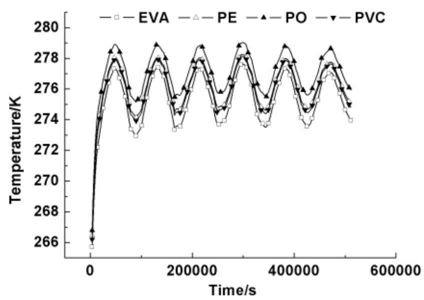


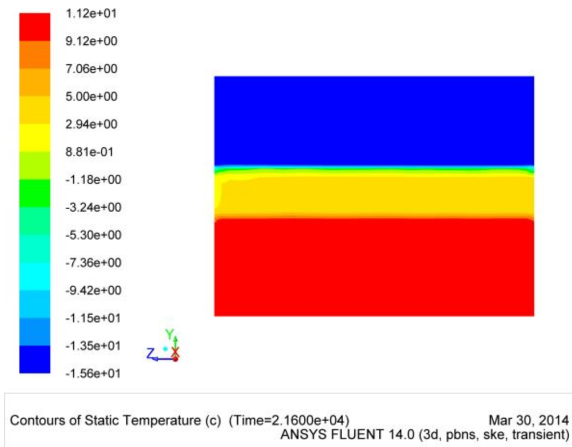
Figure 4. Average ttemperature of air in greenhouse

As shown in Figure 4, the average temperature fluctuations of air in the greenhouse are all 4K when the greenhouse materials are PO, PE, EVA and PVC respectively. The average temperature of air in the greenhouse varies from 275K to 279K when PO is used. The average temperature of air in the greenhouse varies from 273K to 277K when EVA is used. The average temperature of air in the greenhouse varies from 274K to 278K when PE is used. The average temperature of air in the greenhouse varies from 274K to 278K when PVC is used.

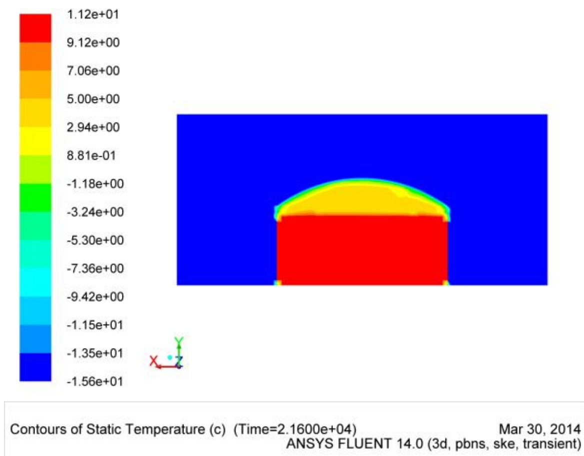
The temperature difference of air in the greenhouse is obvious, while the temperature difference of sewage is not obvious when different materials are used.

3.3 The influence of arch height on insulation effect

The average temperature of air in the greenhouse and average temperature of sewage are monitored when different arch heights are chosen. The influence of solar radiation on the average temperature in the greenhouse and average temperature of sewage is analyzed when different arch heights are chosen. In this case, the greenhouse material is chosen to be PO and the environment temperature is -22℃. The temperature fields are described in Figure 5-7. The average outlet temperature of sewage is described in Figure 8.

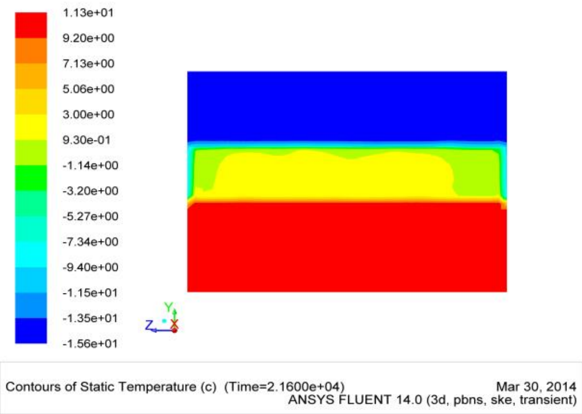


(a) The temperature field at $X=L_x/2$

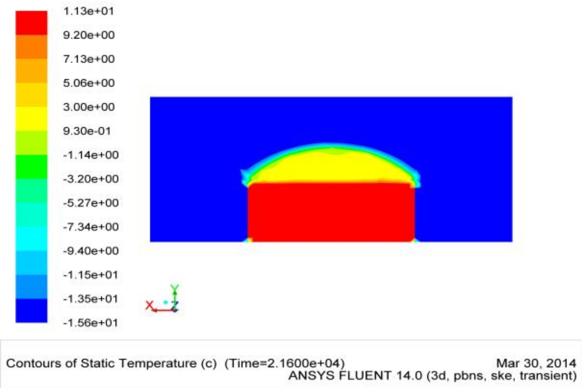


(b) The temperature field at $Z=L_z/2$

Figure.5 Temperature field in greenhouse at $(H-h)$=2m

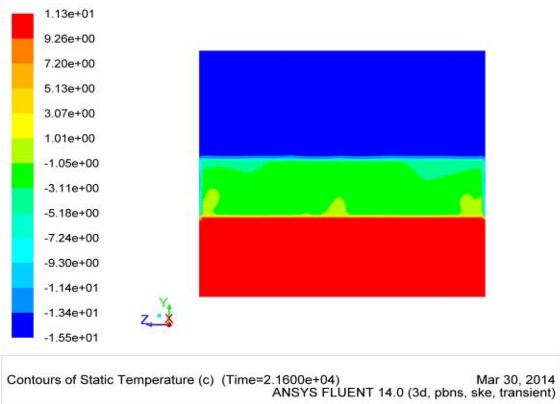


(a) The temperature field at $X=L_x/2$

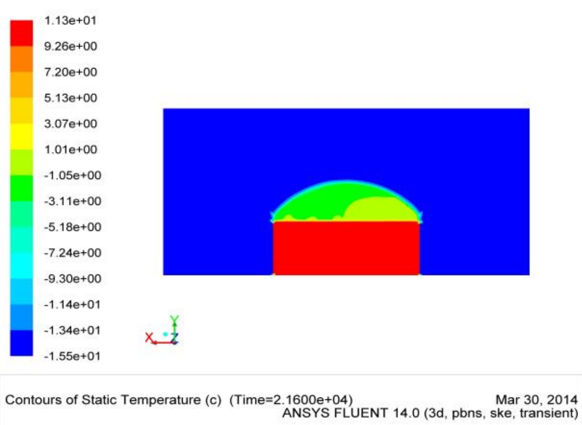


(b) The temperature field at $Z=L_z/2$

Figure 6. Temperature field in greenhouse at (H-h)=2.5m



(a) The temperature field at $X=L_x/2$



(b) The temperature field at $Z=L_z/2$

Figure 7. Temperature field in greenhouse at (H-h)=3m

As shown in Figure 5-7, the average temperature of air in the greenhouse is 3.5℃ when the arch height is 2m. The average temperature of air in the greenhouse is 1.8℃ when the arch height is 2.5m. The average temperature of air in the greenhouse is 0.5℃ when the arch height is 3m. The average temperature of air in the greenhouse reduces as the arch height increases.

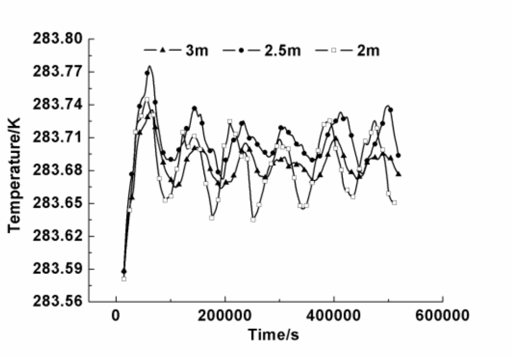


Figure 8. Average ttemperature of air in greenhouse

The trends of the temperature of the outlet sewage are described in Figure 8. The average temperature of outlet sewage is higher when the arch height is 2.5m than that when it’s 2m or 3m. Considered saving material and structural stability, 2.5m is the most appropriate.

3.4 The influence of double-layer film structure on insulation effect

In this paper, the cases are studied when the double-layer film is used. In this case, the greenhouse material is PO and the spacing between the films is 0.5m. The temperature distributions are analyzed when the single and double-layer film are used respectively. The average temperature of air in the greenhouse is described in Figure 9. The average outlet temperature of sewage is described in Figure 10.

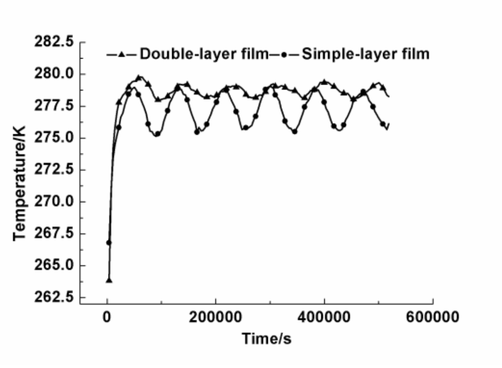


Figure 9. Average ttemperature of air in greenhouse

As shown in Figure 9, the average temperature of air in the greenhouse is from 2.1 to 6.0℃ when single-layer film is used. The average temperature of air in the greenhouse is from 5.1 to 7.0℃ when double-layer film is used. The average temperature of air in the greenhouse is higher when the double-layer film is used than the simple-layer film. The average temperature fluctuation of air in the greenhouse is smaller when double-layer film is used. The double-layer film plays a better role in the effective operation of the sewage treatment.

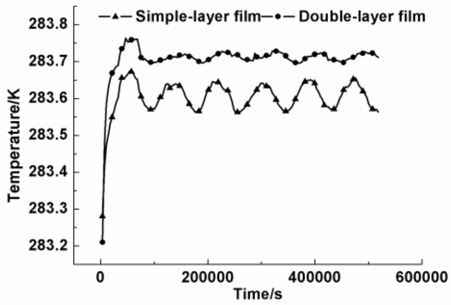


Figure 10. Temperature of sewage

As shown in Figure 10, the average temperature of outlet sewage is from 10.5 to 10.6℃ when single-layer film is used. The average temperature of outlet sewage is from 10.7 to 10.8 ℃ when double-layer film is used. The average temperature of outlet sewage is higher when the double-layer film structure is used than single-layer film structure. The average temperature fluctuation of outlet sewage is smaller when double-layer film is used. The thermal insulation effect is better when the double-layer film structure is used.

4. CONCLUSION

In this paper, the characteristics of the sewage in sewage treatment works are analyzed under low temperature conditions in Northeast China. The numerical simulation and experiment are conducted. The temperature field in the greenhouse and average temperature of sewage are analyzed. The mechanism of heat transfer and flow is analyzed to determine a reasonable greenhouse shape, spatial size, materials, and so on.

The average temperature of the air in the greenhouse is about 4.0℃ and average outlet temperature of sewage is 11.1℃ when the environment temperature is -22℃. The temperature is close to the effective working temperature of an aeration tank. Obviously, the greenhouse insulation plays a good role in the effective operation of the sewage treatment.

The temperature difference of air in the greenhouse is obvious, while the outlet temperature difference of sewage is not obvious when different materials are used. The insulation effect is the best when PO is used while the insulation effect is the worst when PVC is used. The insulation effect is middle when PE and EVA are used.

The arch height of 2.5m is appropriate in the effective operation of the sewage treatment.

The insulation effect is better and the fluctuations of diurnal temperature are comparatively smaller when the double-layer film structure is used compared to the single-layer one

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