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Study on CO_2 removal method in recirculating aquaculture waters

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Abstract

The dissolved CO_2 accumulation has become an important factor restricting production in the high-density recirculating aquaculture system in which pure oxygen injection is used. In this paper, a novel CO_2 removal device is designed for the recirculating aquaculture water environment based on the principle of gas exchange. In terms of experiments, the DOE (design of experiment) method is applied to design three factor two level orthogonal experiment, Further, significance effect of gas to liquid ratios (G / L), inlet CO_2 concentration, the water flow rate (Q_W) on CO_2 removal efficiency is analyzed. Results show that G/L has the most significant influence on the CO_2 removal efficiency. Influences of the latter two on CO_2 removal efficiency are not apparent. Tests results of G/L effect on CO_2 removal efficiency show that, when G/L=1~5, CO_2 removal efficiency increases rapidly with the increase of G/L; when G/L=5, CO_2 removal efficiency=80%~88%; when G/L=8, CO_2 removal efficiency=86%~92% , when G/L>8, CO_2 removal efficiency increases gently with the increase of G/L. Considering both system energy saving and effective removal of carbon dioxide, G/L=5~8 is considered to be the best for the aquaculture water CO2 removal device running, CO_2 removal efficiency=80%~92%.

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1. Introduction

The high concentration of CO_2 is harmful to the fish in aquaculture waters environment. When the concentration of CO_2 exceeds the safe level, the amount of oxygen that the blood hemoglobin of fish can carry is reduced significantly and respiration distress can occur, even with high concentrations of dissolved oxygen in the water. Meanwhile, the whole system's pH also decreases dramatically and the performance of biological purification is affected [1]. In the traditional culture model, because of the low stocking density, CO_2 doesn't accumulate excessively, which doesn't make fish dangerous. In the recirculating aquaculture system, the stocking density raises and the water exchange rate drops (about 10%)[2]. Consequently, large amounts of dissolved carbon dioxide will greatly restrict production. When stocking densities were less than 30 to 60kg/m^3, conventional aeration systems would generally provide sufficient removal of CO_2 through transferring oxygen into the water with airstones, surface agitation and water falls. However, with the increase of the fish density to 100kg/m^3 or higher, in order to make the aquaculture system more productive, pure oxygen systems become a widely used aerobic way to meet the demand of the normal growth of fish for dissolved oxygen,. For every 10mg/L of oxygen consumed, approximately 13–14 mg/L of CO2 excreted through fish gills. As a result, The CO2 accumulates to a high concentration through respiration of the fish and biological nitrification [3-5], which is great toxic to fish. The safe operating levels of CO2 depend on the species, development stage, and overall water quality [6]. In general recommendation, the CO2 concentration of aquaculture water should be less than 10mg/L [7].

CO_2 removal technology of aquaculture waters in china is still in the pilot study stage, generally, a large-scale recirculating aquaculture system does not set CO_2 removal link. However, the United States and Europe have used CO_2 removal device in the intensive recirculating aquaculture systems successively [8-10], the effective CO_2 removal has been achieved and fish production per unit of water has been rised. Currently, the mainstream CO_2 removal devices are stripping columns [11]. Due to a lot of factors, accurately predicting the removal rate is very difficult. In this paper, through three factor two level orthogonal testing, the effect of gas to liquid ratios(G/L), inlet CO_2 concentration, water flow rate(Q_W) and their interactions on the CO_2 removal rate are studied and the best level combinations are discovered to achieve the effective CO_2 removal.

2. Materials and methods

2.1. The testing device and principle

CO_2 removal testing device is a vertical cylinder in which the pickings are irregular or trims are piled up in the supporting plates near to the bottom of the column. Fans blow gas to the bottom. The liquid is poured into the packing shed layer surface by the distributor at the top of the tower, disperses to film in the packing surface, and flows down through the gap between the packing. The packing surface is to be the mass transfer surface of gas and liquid two-phase contact. CO_2 solubility in water is in line with Henry's law, that is, in a certain temperature, the gas solubility in water is proportional to gas partial pressure on the liquid surface, so as long as CO_2 partial pressure in the gas is very small, CO_2 will escape from the water, this process is known as desorption. There is few CO_2 in the air. Its partial pressure is about 0.03% of atmospheric pressure [12-13]. Therefore, air is commonly used as the medium of CO_2 removal device, which is sent to the bottom of CO_2 removal device by the blower. In the packing surface,