SIMULATION OF THE DISPERSION OF ACTIVE SUBSTANCE FOR ALGAE TREATMENT IN AQUACULTURE POND BY COMPARTMENTAL MODELLING

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Abstract

A pilot-scale aquaculture pond has been studied experimentally and by simulation. The objective of this study is to predict the behavior of real ponds when active substances are dispersed at the surface in order to treat algal pollution. Taking into account of hydrodynamics and mass transfer phenomena, a compartmental model has been developed and provides results in good agreement with experimental data. The model is very adaptive and allows extrapolation in a large range of operating conditions. Equations solving is faster than in a classical computational fluid dynamics approach.

Keywords

AQUACULTURE POND, COMPARTMENTAL MODEL, COMPUTATIONAL FLUID DYNAMICS, DISPERSION.

Introduction

An aquaculture pond is defined as an artificial structure used for the fish farming. The presence of nitrates and phosphates coupled with high temperature can cause eutrophication with development of aquatic plants and algae in such an aquatic environment. The treatment of unwanted algae is based on local injection and dispersion of active substances, which have been specially developed for that purpose. A study of the dispersion is needed in order to optimize the localization of the injection point and the concentration of the active substance. CFD simulations and tracer experiment are able to provide such prediction but those methods are sometimes difficult to conduct because of time requirement. Compartmental modelling is an attractive alternative which is able to give results as exact as CFD but with shorter calculation times. It consists in dividing the system’s volume into smaller volumes, named compartments, based on data acquired in tracer experiments, on technical information about the studied pond and/or from preliminary CFD simulations. Each compartment has two important characteristics: (i) a spatial localization (ii) a physically meaningful function. Some authors have already used compartmental approach on a wide field of application and in particular in ponds as (Gresch et al., 2009) and (Alvarado et al., 2012). The aim of this study is to develop a compartmental model on a pilot-scale pond in order to validate the methodology for prediction of dispersion of active substances on real ponds.

Tracer experiment in pilot scale pond

The pilot pond is a parallelepiped reservoir (length = 1.55m, width = 0.7m, height = 0.8m) for an active water volume (V) of 0.4606 m³. Several inlets and outlets (of area = 0.0024 m²) are disposed on each opposite face and can be open or closed. The reservoir is fed with tap water with a volumetric flow rate (Q) in the range from 0.1 to 2 m³/h. The Reynolds number inside the reservoir varies from 100 to 7,300. This large variation of the flow regime (laminar, transition and turbulent flow) makes flow simulation not straightforward despite the apparent simplicity of the system. Experimental residence time distributions (RTD) and local tracer experiments (for dispersion measurement under the assumption that the active substance has the same behavior as an inert tracer) have been conducted using two types of tracers. Chloride sodium was detected with very small lab-made conductivity probes. Rhodamine was detected with a micro fluorimeter. For RTD experiments the tracer is injected at the inlet and the sensor is localized at the
outlet. For local active substance dispersion, injection and detection are made inside the reservoir. The concentration is monitored at eight different points (A, B, C, D, E, F and H) and injection is realized at the center of the surface as depicted in Figure 1. Pulse and step injection protocols have been tested.

![Image of experimental scheme](image)

*Figure 1: Experimental scheme for dispersion studies in the pilot-scale pond. Black dots = sensors. Cross = experimental injection localization.*

**Flow simulation in pilot scale pond**

CFD simulations have been successfully conducted with Fluent 14.5 using the RNG k-ε turbulence model. RTD curves obtained experimentally and by CFD simulation for several configurations are in good agreement. Theoretical (V/Q), numerical and experimental mean residence times give the same values equal to 30 minutes. The simulated velocity vector contour and the shape of RTD curves (a long tail until about one hour) indicate the presence of recirculation loops. Based on RTD experiments and CFD simulations, a compartmental model was then developed. A network of a dozen compartments was established and provides a good representation of the main characteristics of the flow behavior after a few seconds of simulation. From those results the zone where algae are present and active substance is dispersed is not well defined, so that it is impossible to use it as a predictive tool for substance dispersion.

**Dispersion prediction of an active substance**

Local tracer experiment curves obtained experimentally and by CFD simulations have been compared. Figure 2 presents such curves for one specific configuration. The curves have the same tendency but some differences exist due to experimental uncertainty (variable conductivity of tap water for instance). Each curve is valid for only one configuration and need important effort. A compartmental model will give such curves for any configurations with little effort. Due to the very low values of Reynold number in treatment zones, the molecular dispersion cannot be neglected. As a consequence a sub-compartment model is built and takes into account hydrodynamics and mass transfer (convection + molecular diffusion) in the zone of interest. A network of about fifty compartments is finally established. The new network is adapted until it is able to simulate properly the RTD curves and local tracer experiments. Simulations of dispersion of an active substance using the compartmental model were successfully compared with CFD simulations.

![Image of local tracer experiment](image)

*Figure 2: A local tracer experiment. Injection at the center of the surface and detection at point C.*

**Conclusions**

A compartmental model has been successfully developed on a pilot scale pond. The model takes into account hydrodynamics and molecular dispersion. It has been validated by comparison with tracer experiments and CFD simulations. Simulation time is shorter than with CFD simulation and allows having an efficient tool for prediction of active substance dispersion in aquaculture ponds.

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**References**
