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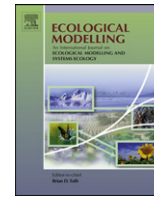

Local calibration of coliforms parameters of water quality problem at Igapó I Lake, Londrina, Paraná, Brazil

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ABSTRACT

This article presents results concerning the local calibration of the transport parameters (longitudinal and transversal diffusions and decay coefficient) for a two-dimensional problem of water quality at Igapó I Lake, located in Londrina, Paraná, Brazil, using fecal coliforms as an indicator of water quality. The simulation of fecal coliforms concentrations all over the water body is conducted by means of a structured discretization of the geometry of Igapó I Lake, together with the finite difference and finite element methods. By using the velocity field, modeled by the Navier–Stokes and Poisson equations, the flow of fecal coliforms is described by means of a transport model, which considers advective and diffusive processes, as well as a process of fecal coliforms decay. In the checkpoint, the longitudinal and transversal diffusion coefficients and the coliforms decay coefficient that best fitted the value of the fecal coliforms concentration were $D_x = D_y = 0.001\ \mathrm{m^2/h}$ and $k = 0.5\ \mathrm{d^{-1}} = 0.02083\ \mathrm{h^{-1}}$. A qualitative and quantitative analysis of the numerical simulations conducted in function of the diffusion coefficients and of the coliforms decay parameter provided a better understanding of the local water quality at Igapó I Lake.

1. Introduction

The concern with water pollution has motivated the development of practices for the calibration of mathematical models by means of numeric simulation of flow and transport. Calibration refers to the process by which parameters estimates are made through observed data. Calibrated and validated models, in relation to the current conditions of a water body, may be used as water quality monitoring tools (Reckhow and Chapra, 1983; Janssen and Heuberger, 1995).

Historically, the problem of water quality began with the work proposed by Streeter and Phelps (1925). This model described the consumption process of oxygen and the reaeration capacity of the water body by means of two first order ordinary differential equations, considering permanent and uniform flow. Due to lack of computer tools, the models from 1920s to 1960s were one-dimensional and limited to the primary treatment of effluents in streams or estuaries with linear kinetics and simple geometries. Such models presented analytical solutions. Subsequently, during 1960s, technological advances allowed numerical approaches in more complex geometries. The focus started to be the primary and secondary treatment of effluents and the transport of pollutants in streams and estuaries, modeled in two dimensions. In this period, based on O'Connor and Dobbins's (1958) proposal, the models were described by second order differential equations, which added benthonic and photosynthesis demand treatment to the models of the first period. In 1970s, the water body started to be observed as a whole. The eutrophyzation process, excessive proliferation of algae caused by nutrients in excess, was the focus of the models. Therefore, representations of the biological processes started to be studied in streams, lakes and estuaries. Simultaneously, non-linear kinetics and three-dimensional models also started to be studied by means of numerical simulations. At that time, due the concern with the environment, the ecological movements increased in some sectors of the society. In this context, in 1971, the Texas Water Development Board (TWDB) created a one-dimensional Water Quality Model (QUAL-I), which allowed the description of advective and diffusive/dispersive transport of pollutants in water bodies (TWDB, 1971). Lately, the United States Environmental Protection Agency (USEPA) improved the QUAL-I model, which started to be called QUAL-II, simulating up to 13 species of parameters indicative of water quality in deeper rivers (Roesner et al., 1981). In the beginning of 1980s there was the emergence of the Task Group on River Water Quality (TGRWQ),

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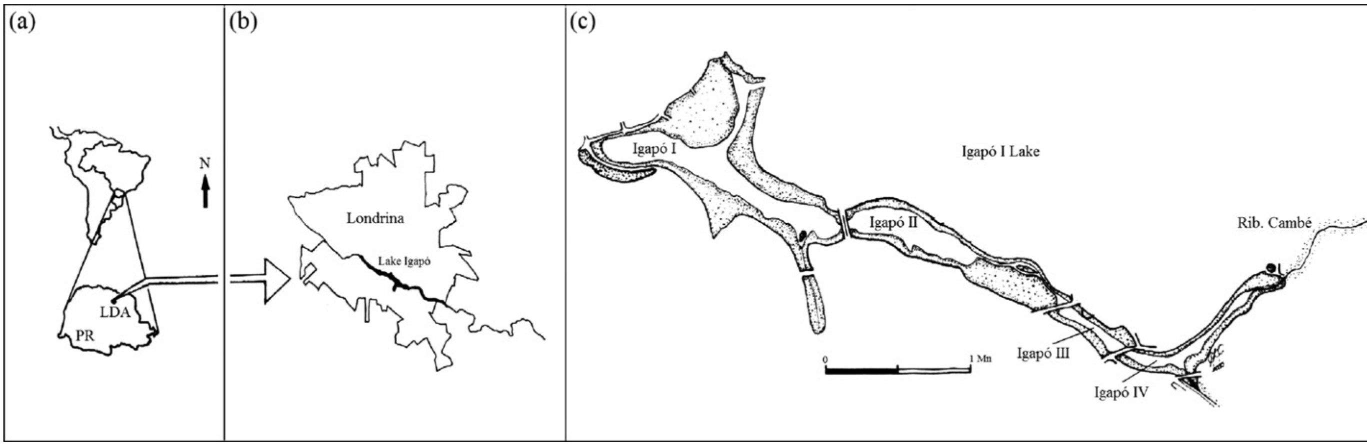

Fig. 1. (a) South America, Brazil and Paraná State. (b) City of Londrina with Igapó Lake highlighted. (c) Map of Igapó Lake, Londrina, Paraná.

a group of scientists and technicians organized by the International Association on Water Quality (IAWQ), which standardized the existing models and manuals. In 1987, due to the several modifications in the QUAL-II model, it was renamed QUAL2E, simulating up to 15 species, accepting punctual and non-punctual sources and fluids both in permanent and non-permanent regime (Brown and Barnwell, 1987). The QUAL2K model (Chapra et al., 2007) is the current improved version of the QUAL2E model. Parallel to that, in 1985, the USEPA developed the water analysis simulation program (WASP), which simulated one-dimensional, two-dimensional and three-dimensional processes of conventional and toxic pollutants. This model was also modified several times and its current version is the WASP7 (Ambrose et al., 2006). Other numerous water quality models can be found in the literature, such as the river water quality models (RWQM), also developed by IAWQ (Shanahan et al., 2001), the hydrological simulation program-fortran models (HSPF), developed by USEPA (Bicknell et al., 2001), among others.

Since those mathematical models are extensively used as water quality monitoring tools, these models must be calibrated and validated in order to minimize errors involved in the predictions. The calibration is the first testing of the model obtained from comparison of the field observations with the model predictions. However, due the dynamic nature of the environment, there are differences between the predicted and observed results (Peter, 1998).

In this context, this article presents results concerning the local calibration of transport parameters for a two-dimensional problem of water quality at Igapó I Lake, located in Londrina, Paraná, Brazil, using fecal coliforms as an indicator of water quality. Fecal coliforms bacteria are found in the intestinal tract of humans and other hot-blooded animals. Although fecal coliforms bacteria are not necessarily dangerous to men, high concentrations in water bodies indicate hazards for the human health (Frenzel and Couvillion, 2002). Thus, the local monitoring of such concentrations consists of a method to identify the contamination magnitude, and a very well calibrated mathematical model may be used to describe such local pollution (Reckhow and Chapra, 1983; Janssen and Heuberger, 1995; Himesh et al., 2000).

The simulations of fecal coliforms concentrations all over the water body are conducted by means of structured discretization of the geometry of Igapó I Lake (Thompson et al., 1985; Zang et al., 1994; Cirilo and De Bortoli, 2006; Pardo et al., submitted for publication). By using velocity field, modeled by Navier–Stokes and Poisson equations (Whitfield, 1983; Schlichting and Gerten, 2000; Fox et al., 2006), the flow of the fecal coliforms is described by means of a transport model, which considers advective and diffusive processes, as well as a process of removing of fecal coliforms. This advection–diffusion-reaction model, which models the fecal coliforms concentrations at Igapó I Lake, is resolved by a semi-

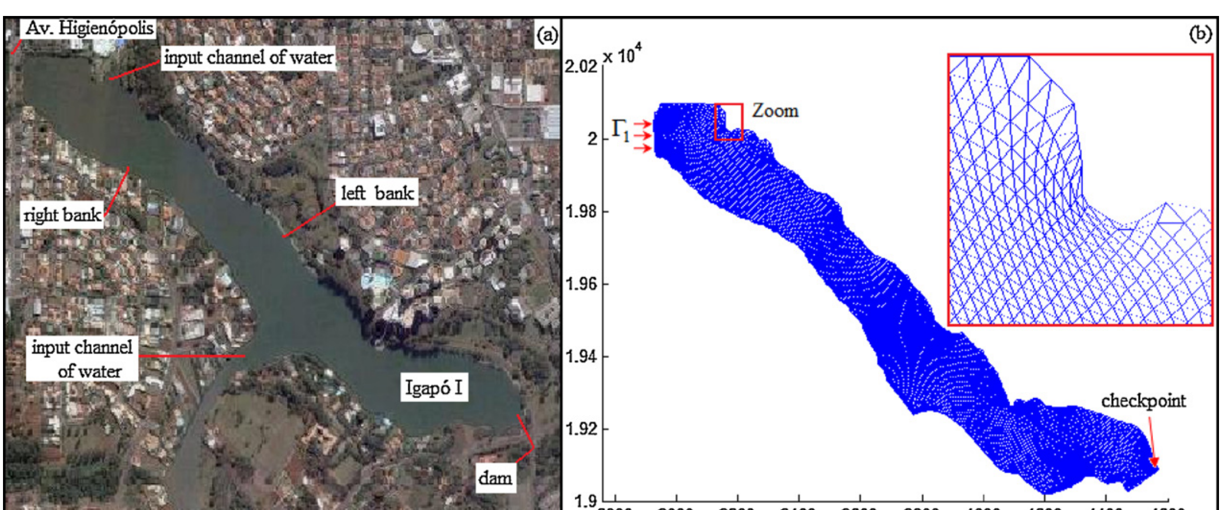

Fig. 2. (a) Physical domain of Igapó I Lake. (b) Computational grid, where Γ_1 points are the input of the lake, considered as boundary conditions in the model, and checkpoint is the point of calibration of the numerical simulation.