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Numerical routing of tracer concentrations in rivers with stagnant zones
Abbas Parsaie and Amir Hamzeh Haghiabi

ABSTRACT
Modeling pollution transmission in rivers is an important subject in environmental engineering studies. Numerical approaches to modeling pollution transmission in rivers are useful tools for managing the water quality. The advection-dispersion equation is the governing equation in the transport of pollution in rivers. Recently, due to advances in fractional calculus in engineering modeling, the simulation of pollution transmission in rivers has been improved using the fractional derivative approach. In this study, by solving the fractional advection-dispersion equation (FRADE), a numerical model was developed for the simulation of pollution transmission in rivers with stagnant zones. To this purpose, both terms of the FRADE equation (advection and fractional dispersion) were discretized separately and the results were connected using a time-splitting technique. The analytical solution of a modified advection-dispersion equation (MADE) model and observed data from the Severn River in the UK were used to demonstrate the model capabilities. Results indicated that there is a good agreement between observed data, the analytical solution of the MADE model, and the results of the developed numerical model. The developed numerical model can accurately simulate the long-tailed dispersion processes in a natural river.

Key words | advection-dispersion, dead zone, fractional, numerical model, river pollution

NOMENCLATURE

\( \lambda \) | dead zone effect
\( \kappa \) | ability to self-clean
ADE | advection-dispersion equation
C | concentration
\( D_L \) | longitudinal dispersion coefficient
FRADE | fractional advection-dispersion equation
MADE | modified advection-dispersion equation
TSM | transient storage zone

INTRODUCTION

The study of river water quality is an important issue in environmental studies (Cho 2016; Qishlaqi et al. 2016; Wang 2016). Modeling contaminant transmission in rivers is one aspect of studying river water quality (Rathnayake 2015a; Parsaie & Haghiabi 2015b; Guan et al. 2016; Xu et al. 2016). Studies on pollution transmission have been conducted using field measurements and numerical simulations (Parsaie & Haghiabi 2015a; Rathnayake & Tanyimboh 2015). In field studies, to define the mechanism of pollution transmission, a tracer is injected and its concentration is routed along the river (Toprak et al. 2004; Noori et al. 2011a, 2011b; Tutmez & Yuceer 2015; Toprak et al. 2014; Zeng & Huai 2014). In other words, to characterize the effects of hydraulic and geometric properties of rivers such as dead or stagnant zones, a profile of the concentration of the tracer at a number of sampling stations is evaluated (Rathnayake 2015b; Farhadian et al. 2016; Wang & Huai 2016). One of the main parameters related to studies of river pollution is longitudinal dispersion coefficient \( (D_L) \) (West & Mangat 1986; Seo & Cheong 1998, 2001; Kashefipour & Falconer 2002). This parameter is usually derived by routing the concentration of tracer along the river. Recently, advanced numerical approaches...