Available online at www.sciencedirect.com

ScienceDirect

Procedia Environmental Sciences 25 (2015) 74 – 81

Procedia Environmental Sciences

7th Groundwater Symposium of the
International Association for Hydro-Environment Engineering and Research (IAHR)

Laboratory estimation of dispersivity coefficients

F. Cupola[a], M. G. Tanda[a] and A. Zanini[a]*

[a]*University of Parma, Department of Civil, Environmental Engineering and Architecture, Parma, Italy*

Abstract

The dispersion phenomena in aquifers through experimental activities have been extensively studied in the past; recently the availability of digital images of the transport process made possible the development of new techniques for the evaluation of the dispersivity coefficients (Sànchez et al., 2008, 2011). This work shows the application of an innovative procedure that allows a detailed estimation of longitudinal and transverse dispersivities in an experimental plume devised in a laboratory sandbox. The dataset was provided processing the results of a sandbox developed at the hydraulic laboratory of the University of Parma (DICATeA). The equipment represents a 2-D unconfined aquifer controlled through two constant head levels (upstream and downstream); it consists of a PMMA tank filled of 1 mm glass beads as porous medium. An injector was placed inside the porous medium and sodium fluorescein salt was used as tracer. The tests consist of injecting a known solution discharge for a specific time duration and then observing the plume through the collection of side wall images obtained by means of a digital camera (see Citarella et al. (2010) and Cupola et al. (2014) for more details). The study case presented in this work considers a homogeneous porous media and a uniform flow in the vertical plane; the plume develops according to 2-D plane advection-dispersion equation. The pictures were collected with time interval equal to 5 s. Using the collected frames, it is possible to estimate the concentration in each point of the domain at different times and also the partial derivatives of the concentration in space and time. This information allows easily to estimate the two dispersivity coefficients using the Advection-Dispersion equation. This analysis was carried out for each picture collected during the test (about 650). The results showed, as expected, that the longitudinal dispersivity presents the same order of magnitude of the pore dimension and the ratio between longitudinal and transverse dispersivity is constant through the whole domain, although higher than that reported in literature. Even though the dispersivities are estimated for each pixel of the figures, only a few of them provide reliable information; in fact, only on the plume boundaries a significant variation in concentration could be detected. For this reason a selection criterion for the credibility of the results was developed. Future developments will estimate the apparent dispersivities considering a heterogeneous media.

Peer-review under responsibility of the Scientific Committee of the IAHR Groundwater Symposium 2014

Keywords: Groundwater transport, image analysis, sandbox

* Corresponding author.
E-mail address: andrea.zanini@unipr.it

Peer-review under responsibility of the Scientific Committee of the IAHR Groundwater Symposium 2014
doi:10.1016/j.proenv.2015.04.011

1. Introduction

Laboratory experimental equipment (sand-boxes) has been adopted with the aim of studying two dimensional (on the vertical plane) heterogeneous porous media in order to carry out experiments in a controlled environment (e.g. Bruch, 1970; Silliman and Zheng, 2001; Sternberg, 2004; Goswami and Clement, 2007; Yin and Illman, 2009 and Cupola et al., 2014). With reference to the study of dispersivity coefficients through experimental devices in particular, Silliman et al. (1987) investigated the longitudinal dispersion in anisotropic porous media by using sodium chloride as tracer, finding a relationship between dispersion and hydraulic anisotropy. Aksoy and Guney (2010) investigated the longitudinal and transverse dispersivities reproducing a homogeneous 3-5 mm sandy aquifer. Kim et al. (2004) conducted a laboratory tracer test representing a two-dimensional aquifer with the aim of estimating the longitudinal dispersivity (α_L) and the ratio (α_T/α_L) of transverse to longitudinal dispersivity of sandy aquifer material. Building on this background, in the hydraulic laboratory of the Department of Civil, Environmental and Land Engineering and Architecture (DICATeA) of the University of Parma, we set up an experimental device to perform groundwater transport tests.

The guiding principles of our experimental activities were to:

1. develop a non-invasive monitoring system with respect to the flow and concentration field;
2. analyze whether the present potential of digital photography (color camera with high resolution) improves the detection of concentration in terms of reading and spatial detail;
3. implement the experimental runs by adopting substances and methodologies harmless for both the people and the environment;
4. develop a method that monitors the experimental errors in order to validate the data collected;
5. test a new procedure for estimating the dispersivity coefficient values.

In this paper we describe materials and methods of the laboratory experiments, the results of a meaningful experimental test case and the procedure for estimating the dispersivity coefficients.

2. Experimental device

The transport experiments were performed in a laboratory device (sandbox) built with polymethyl methacrylate (PMMA) plates. The sandbox reproduces an unconfined aquifer governed by two constant water level boundary conditions (upstream and downstream). The external dimensions of the sandbox are 0.73 m × 1.20 m × 0.14 m. Along the longest axis x, the sandbox is made up of three parts (Fig. 1): two tanks (upstream and downstream), which allow the regulation of the water level and, as a consequence, of the flux, and a central chamber (0.70 m × 0.10 m × 0.95 m) which contains the porous medium. The water discharge is monitored with a flow meter and the water exiting the sandbox was conveyed to the sewage system. The porous medium consists of glass beads with diameter in the range between 0.75 and 1 mm with density of 1480 kg/m^3 and density equal to 37%. After several tests carried out with different hydraulic gradient, the bulk K of the glass beads was estimated at about $6 \cdot 10^{-3}$ m/s. In the upstream part of the sandbox an injector was positioned (see Fig. 1) and fluorescein sodium salt was chosen as tracer because mixed with water and excited with blue light (λ = 490 nm) it irradiates in longer wavelength (green light, λ = 520 nm). The experimental device was placed in a darkroom to avoid all the external light contamination and lightened by 8 monochromatic blue LEDs.

All variables, such as upstream and downstream level, injected discharge, temperature, background discharge, start and ending of injection, were acquired by means of data acquisition system. The luminosity at each point of the sandbox is recorded by a digital camera and then converted in concentration through an imaging technique. A comparison between the mass released by the injector and the one estimated through the image processing has been made to evaluate the reliability of data collected. Another confirmation of the validity of the data used was given comparing the mass rate that flows through the sandbox with the known injected one. During the calibration of the device, the maximum