Numerical & Experimental Study of Flow from a Leaking Buried Pipe in an Unsaturated Porous Media

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***Abstract*—**Considering the numerous applications of the study of the flow due to leakage in a buried pipe in unsaturated porous media, finding a proper model to explain the influence of the effective factors is of great importance.There are various important factors involved in this type of flow such as: pipe leakage size and location, burial depth, the degree of the saturation of the surrounding porous medium, characteristics of the porous medium, fluid type and pressure of the upstream.In this study, the flow through unsaturated porous media due to leakage of a buried pipe for up and down leakage location is studied experimentally and numerically and their results are compared. Study results show that Darcy equation together with BCM method (for calculating the relative permeability) have suitable ability for predicting the flow due to leakage of buried pipes in unsaturated porous media.

***Keywords*—**Buried, Leaking pipe, Porous media, Unsaturated

I. Introduction

STUDY of the fluid flow due to leakage in a buried pipe have various applications like leakage location detection in oil and gas pipelines, subsurface irrigation, nuclear disposal, landfills and etc. Among these applications, subsurface irrigation due to the shortage of water recourses is of great importance in today's world.

In this method of irrigation, the leaking pipes are laid near the roots of the plants so the required amount of the water for the plants shall be directed to them. The most important advantage of this method is preventing evaporation of a significant proportion of the water. Volume of the water penetration through the soil and the pattern of the penetration are two factors which affect the design of this type of irrigation system. Initially, Philip in 1968 presented an analytical solution for a buried source of mass in unsaturated soil for both two and three dimensional geometry [1].In 1986, Schwartzman investigated the role of leakage distance on flow propagation and volume of the wetted soil [2].

With progress in computer abilities for numerical solutions, the first numerical solution in this subject was presented by Cho in 1996 [3].

More extensive numerical and experimental studies are performed in this field [4-8]. Base on the knowledge of the authors all the above studies reviewed the problem from agricultural point of view and for numerical solutions commercial software (such as HYDRUS) for irrigation systems is used. Yet, the problem was not studied in the context of fluid dynamics.

In this paper both experimental and numerical methods have been used.

Initially, the way the simulation was conducted is outlined and then experimental method is described and at finally the results of the two methods are compared together

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II. Problem Description

For Modeling a pipe in a semi-infinite porous media the configuration (figure 1) is considered. The dimensions for representing the semi-infinite porous media are selected base on [9] which state that the proper ratio of width to radii is 1/30 which represents the semi-infinite porous media. The geometry considered is a horizontal pipe with a radius of ri embedded in a unsaturated porous medium at a depth of d ($d/r_i = 5$ for the present study) beneath the top surface. A crack developed on the pipe is assumed to have an angular span of 9^o to produce leakage from the pipe. Two locations of the leakage are considered in the present study: one is on the top and another at the bottom of the pipe. The fluid is assumed to discharge from the horizontal pipe at a radial velocity of U_R.

III. Governing Equations

Considering the numerous factors which are important and affect this type of flow, it is necessary to reduce the desired factors to study the problem and with some simplifications. In this regard, the assumptions below are considered:

The porous media is homogeneous, isotherm and unsaturated. No reaction occurs within the porous medium. The flow is two dimensional, laminar and incompressible.

In the current study for flow study of a leaking buried pipe in an unsaturated porous media, it is necessary to use multiphase relationships. The geometry of the problem is shown in figure 1.

At the beginning of the flow, it is supposed that: there is no water in the void volumes of porous media and it is filled with air (similar to a real condition), and gradually the water exits from the leakage and fill the void volumes. In this paper, the following dimensions are selected: $\frac{d}{r_i} = 5$, $\frac{w}{r_i} = 30$.