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Simulation of external contamination into water distribution systems through defects in pipes

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Water quality can be defined as a set of properties (physical, biological and chemical) that determine its suitability for human use or for its role in the biosphere. In this contribution we focus on the possible impact on water distribution systems quality of external contaminant fluids entering through defects in pipes.

The physical integrity of the distribution system is a primary barrier against the entry of external contaminants and the loss in quality of the treated drinking water, but this integrity can be broken. Deficiencies in physical and hydraulic integrity can lead into water losses, but also into the influx of contaminants through pipes walls, either through breaks coming from external subsoil waters, or via cross connections coming from sewerage or other facilities. These external contamination events (the so called pathogen intrusion phenomenon) can act as a source of income by introducing nutrients and sediments as well as decreasing disinfectant concentrations within the distribution system, thus resulting in a degradation of the distribution water quality.

The objective of this contribution is to represent this pathogen intrusion phenomenon. The combination of presence of defects in the infrastructures (equipment failure), suppression and back-siphonage and lack of disinfection is the cause of propagation of contamination in the clean current of water. Intrusion of pathogenic microorganisms has been studied and registered even in well maintained services. Therefore, this situation can happen when negative pressure conditions are achieved in the systems combined with the presence of defects in pipes nearby the suppression. A simulation of the process by which the external fluids can come inside pipes across their defects in a steady-state situation will be considered, by using different techniques to get such a successful modeling, combining numerical and experimental simulations.

The proposed modeling process is based on experimental and computational simulations. An analysis of the intrusion behavior considering hydrodynamic and transportation of pollutant phenomena has been developed, comparing the influence of the turbulence consideration and the agreement of both computational and experimental results. This paper is focused on the analysis of such external intrusion phenomenon, the relationship between the income flow and the pressure inside the pipe, depending on the characteristics of the defect and the pressure level, as well as the effect on the water quality of the income substances dispersion.

Two different experiments have been developed. In order to represent the intrusion phenomenon in steady state, two suitable assemblies have been implemented in the laboratory. In a lower order of pressures a Venturi tube has been used for generating the depression. In a higher level of pressures, a pumping system has been used. The defect on the pipe has been simulated by a circular hole, and the dispersion of pollutant has been considered by means of salinity as a conservative contaminant. The simulated scenarios of different suppressions can vary from 0.001 to 0.7 bars.

The prototypes are also simulated by numerical modeling in two and three dimensions using Computational Fluid Dynamics techniques. For this purpose Fluent 6.3™ has been used, which displays the fields of hydrodynamic components and salinity. After doing a proper calibration process, the contrast made between models will allows us to establish the foundation for further pathogen intrusion simulations in the distribution system. Different turbulent models based on turbulent viscosity and different boundary conditions will also be considered. The agreement between experimental and computational models will be analyzed, and the differences between series of results will be compared, validating thus the use of computational models for representing the pathogen intrusion problem. By both, mathematical and physical models, it is intended to have a better knowledge of quantities that can not be measured, such as velocity fields, aspects of turbulence, pressure fields, concentrations, etc. existing in mixing processes related to external intrusion.