

Understanding flow dynamics in drinking water storage tanks

Summary

Drinking water storage tanks are essential components of water supply systems to store water, to level off pressure in networks and to meet emergency storage. They are also frequent sources of deterioration of drinking water quality and safety owing to inadequate tank design and operation. Mostly, existing tanks design, dimensions and operation do not account for water mixing and renewal.

The current research aims to understand the flow dynamics inside water storage tanks to find practicable solutions to improve their design and rehabilitation and to support their operation to improve water mixing and to reduce water ageing. The methodology is based on experimental tests carried out in laboratory small-scale tanks, specially assembled for this research, as well as, on field tests in full-scale tanks. Three sets of experimental tests are carried out: traditional tracer tests to determine water residence time distribution and to calculate mixing, renewal, and plug-flow indexes; dye tracer tests to provide a qualitative understanding of the preferential flow paths; and Particle Image Velocimetry (PIV) tests to determine velocity fields and to assess turbulence intensity. Structural and operational characteristics, such as, tank cross-section shape, inlet and outlet pipe location, inlet pipe diameter, number of inlet pipes, inclusion and size of baffles, jet inflow, fluctuation of stored water, are experimentally analysed for assessing their effectiveness in water mixing and renewal. Full-scale tests operated under fill-and-draw mode provide complementary information on water mixing and residence time.

The main outcomes of this research are: (i) the characterization of water storage tanks in Portugal, focusing on the main physical characteristics and operational conditions; (ii) the study of mixing conditions and water ageing in small-scale circular and rectangular cross-section storage tanks; (iii) the analysis of the effect of the fill-and-draw cycles on the water mixing and renewal in small-scale and full-scale conditions; (iv) the proposal of a new empirical formula for estimating the turnover time in circular cross-section tanks operated at a constant level; (v) the study of flow dynamics conditions using PIV technology; (vi) the analyses of several improvement measures of water mixing and renewal and the identification of the most adequate measures for different circular cross-section tanks; and (vii) the proposal of two water mixing models and the prediction of chlorine decay inside water tanks.

Keywords

Water storage tanks, drinking water safety, residence time distribution, particle image velocimetry, chlorine decay.



Interior view of a circular cross-section water storage tank.



PhD student

Alexandre da Silva Pinheiro

PhD program

Civil Engineering (IST, University of Lisbon)

Supervisor

Dídia Covas (CERIS, IST, University of Lisbon)

Co-supervisors

Maria do Céu Almeida (LNEC) and Laura Monteiro (IST, University of Lisbon)

Period

2017-2022

Funding

IST – LNEC Joint Doctoral Initiative (PD/BD/135214/2017)