# Localization of Contamination Sources in a Drinking Water Distribution System: A Method Based on the Residence Time of Water in Pipes

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Contamination of critical infrastructures, such as drinking water distribution systems (DWDS), by chemical, biological or radiological agents can have major public health, economical and psychosocial consequences. Vulnerability of drinking-water distribution systems to deliberate attacks is one of the main issues of concern to regulatory agencies and water utilities.
In case of a deliberate contamination of the drinking-water distribution systems, it is important to know the probable localization of point sources of contamination and subsequently the contaminated areas allowing the specification of delimitation areas to perform corrective actions.
One possible approach for solving this problem is the inverse simulation which allows estimating the localization of point sources for contamination, analysing the concentration profiles in several check points along the network. Several studies that have been developed in the last years using this approach, such as simulation-optimization based methodologies (Laird et al., 2006), coupled model trees-linear programming algorithm (Preis et al., 2006), Bayesian inversion techniques (Propato et al., 2010) and contamination status algorithms (De Sanctis et al., 2010).
Even with all of these developments, there are yet several challenges to be addressed. The effect of uncertainties and errors in the data provided by the sensors and the size of the time interval needed to perform accurate source identification are some good examples.
The main objective of this work is to present a different methodology for the localization of contamination sources, based on the analysis of the residence time in pipes. Through this methodology, there is no need to have accurate values for the contaminant concentrations in sensors. The methodology is based on binary sensor status over the time.
A drinking water distribution system is generally constituted by a set of links (pipes, pumps and valves) and storage facilities allowing the transport of drinking water from different sources to consumers. The links are connected at junction nodes, forming complex networks.
The proposed methodology is based on three algorithms, which constitute a different approach to solve the problem of the localization of possible contamination sources in DWDS. The first algorithm (Algorithm A) allows the description of the different paths that a contaminated water parcel can take from a contamination source. The second algorithm (Algorithm B) allows the evaluation of all possible contamination sources that could explain a positive reading in each sensor. Algorithm B runs in reverse time. These algorithms are based on similar concepts to the particle backtracking algorithm presented by Shang et al. (2002). These two algorithms are the starting points to run the third proposed algorithm (Algorithm C), which performs the localization of contamination sources based on the information gathered by sensors.
Figure 1 presents an example of a real DWDS, constituted by 1 reservoir, 571 junction nodes, 919 pipes and 3 tanks. The hydraulic behaviour was analysed using the EPANET Programmer's Toolkit in Visual Basic and the hydraulic data was exported to MATLAB.
The methodology was tested for 5 simultaneous simulated contaminations, at nodes A, B, C, D and E, occurring at t=0 h. Figure 1 also shows the localization of the contamination sources (coloured diamonds) and sensors (green points). It was simulated the transport of the contaminants throughout the network for determining the times of the first detection for each sensor.
Figure 2 presents the results obtained by the proposed methodology for a time horizon of 24 hours.

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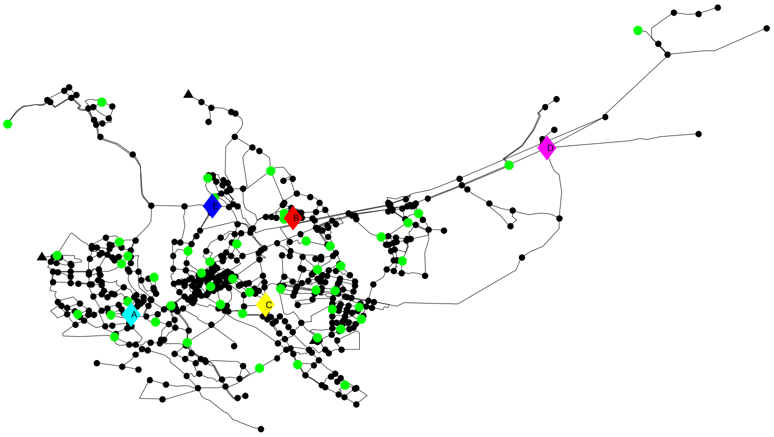

Figure 1 – Real DWDS with the localization of the contamination sources simulated.

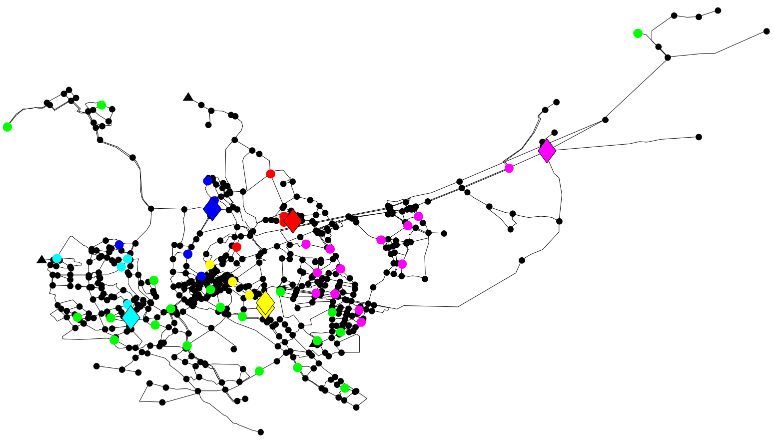

Figure 2 – Results for the localization of contamination sources with a time horizon of 24 hours.

Through the analysis of Figure 2, it is possible to observe that several sensors didn't detect any contamination (green points). However, all simulated contaminations were detected in first place for at least on sensor, allowing to infer the possible localizations for each contamination. The contamination C (represented in yellow) had two possible contamination sources.

The proposed methodology is not affected by the uncertainties in the measure of concentrations in sensors because is based only on the binary sensor status over the time. It was possible to achieve good results for the localization of each contamination knowing only the hydraulic characteristics of the network and the time of the first detection for each sensor.

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