CONTAMINATION SOURCE DETECTION IN WATER NETWORKS UNDER DEMAND UNCERTAINTY

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Accidental or intentional drinking water contamination in urban distribution systems may cause great danger for public health. Methods for detecting contamination and for localizing the pollution source are then required. While many recent studies were devoted to the task of quality sensor placement on a water distribution network, the source identification problem was less investigated. Source identification is the inverse problem of water quality simulation in a hydraulic network, which can be solved in direct or indirect ways. In this work a procedure able to identify source and input magnitude of an accidental intrusion of pollutant in a hydraulic network using time-varying concentration measurements is presented. The methodology solves the inverse problem in an indirect way, based on a pathway analysis of the network and on the demand coverage concept, which assumes that quality state at a sampling node provides information about quality at the upstream nodes (*covered nodes*). In a first step, a subset of candidate nodes than may be potential source of pollutant is individuated. Then, among candidate nodes the source is identified solving a linearized optimization problem, which incorporates a hydraulic network simulation model.

It is important to note that source identification inverse problems may be ill-posed and then their results may depend strongly on the input data quality (Polis and Goodson 1976). This aspect can be crucial in a water quality inverse problem, in which nodal demands during concentration measurements are required. In fact, since the real water demands cannot be known, a mean time pattern is usually assigned in each node. So, among inverse problem input data, water demands have a high level of uncertainty. For this reason, only source identification procedures, robust respect to such uncertainty, could be applied to real networks.

As direct solution of inverse problems, the proposed indirect methodology requires the knowledge of consumer water demands in each node during concentration measurements. In order to verify the robustness of the proposed methodology respect to water demand uncertainty an analysis based on a Montecarlo procedure is performed. In particular, the mean temporary demand pattern assigned for methodology application is perturbed considering that nodal demands vary around the mean value following a gaussian distribution with an assigned variance. The perturbed patterns obtained in this way are used for generating synthetic measured concentrations. The distribution system used for the application is the well known *Anytown* network (Walski et al., 1987). The Epanet software is used as network simulator. In order to investigate the effect on the methodology results of different levels of uncertainty 2000 patterns are generated from a gauss distribution perturbing the mean pattern using four different values of coefficient of variation CV = 0.1, 0.3, 0.5, 0.7. Such tests are realized considering different number of concentration measurements for day: four measurements every six hours; eight measurements every three hours; twelve measurements every two hours. For all investigated cases, in Figure 1 the identification frequency of the right source node 70 is plotted against the four considered coefficient of variation values of the demand pattern. Using four measurements for day, the identification frequency of node 70 varies from the 100% for a coefficient of variation 0.1 to the 74.1 % in case of a coefficient of variation equals to 0.7. For the cases with CV>0.1, with eight measurements the identification frequency of node 70 values are greater than the corresponding values obtained with four measurements. In particular, the frequency varies from the 100% for CV= 0.1 to the 83.8 % for CV= 0.7. Instead, with twelve measurements none improvement in source identification is observed respect to the case with eight measurements per day, in fact for example with CV=0.7 the identification frequency is 83.85%. This denotes that there is a correlation between measurements, which should be taken in account in fixing the measurements frequency.

In all cases the mean error on estimated input concentration is about the 10%, which seems widely acceptable. Such results show that the source identification methodology is sufficiently robust respect to water demand uncertainty and it can be applied to real world situations.

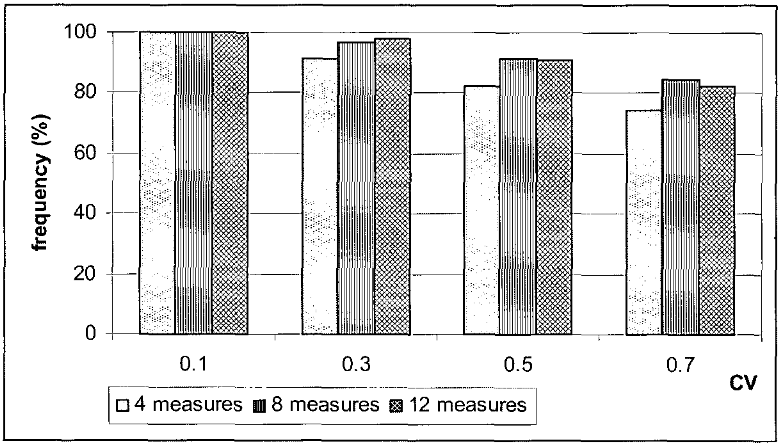

Fig. 1 Identification frequency of the right source node 70 against coefficient of variation.

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