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Experimental proof of contaminant ingress into a leaking pipe during a transient event

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Abstract

It has been hypothesised that negative transient pressures may result in ingress of contaminated groundwater through leakage orifices. This paper presents results of contaminant ingress tests from a novel laboratory facility at the University of Sheffield. An engineered leak surrounded by porous media was subjected to a pressure transient resulting from the rapid closure of an upstream valve. It has been shown that a pollutant originating externally was drawn in and transported to the end of the pipe loop. Thus this paper presents the first fully representative results of contaminant ingress.

Keywords: Pressure transient; contaminant ingress; water quality; leakage

1. Introduction

Water distribution authorities are expected to continuously supply clean and safe drinking water, failure to meet this expectation may have financial repercussions, but more importantly could affect public health. Leakage from water distribution systems (WDS) is a well-documented issue which impacts both customers and suppliers, in England and Wales the average reported levels of leakage for 2009-2010 were estimated at 131 litres per property (OFWAT, 2010). A less well understood and quantified phenomenon in WDS are pressure transients, which can result in negative pressures. When negative pressures are combined with leaks, there is a risk of contaminant

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ingress. Such ingress could result in possible incidents of water quality deterioration and failure to meet prescribed standards (Lechevallier et al., 2003). A UK study (Hunter et al., 2005) into self-reported diarrhoea in a control group found a strong association between reported cases of diarrhoea and low pressures at consumer taps thus providing a feasible assertion that the presence of low pressures within distribution systems is associated with contamination events.

While it is generally accepted that negative pressures can result in ingress from surrounding groundwater there is a perception that, due to the short duration, oscillating nature of pressures transients, only water which has been expelled from the distribution system will re-enter the pipe or that if contaminant is intruded it will be expelled on the next positive pressure cycle. In order to ascertain if a contaminant originating external to a pressurised pipeline can be intruded and remain within the pipeline, thus posing a risk to water quality, an innovative physical investigation was designed and implemented. The work presented here aims to explore via fully representative, but extreme, physical experiments if a contaminant originating external to a pressurised pipeline can be intruded and remain within the pipeline.

2. Contaminant Ingress

For contaminant ingress to occur, three requirements must coexist; a contaminant source external to the distribution pipe, a pathway providing a route into the system (e.g. leak orifice, joint failure, flooded air valve chamber) and a driving force such as a pressure transient or sustained low pressure (Lindley & Buchberger, 2002).

2.1. Contaminant Source

An AWWA Research Foundation sponsored study (Kirmeyer et al., 2001) quantified the pathogens that occur in the ground surrounding mains water pipes. Within the investigation, researchers collected soil and water samples external to existing water pipelines from six different U.S. states and tested for a range of microbial indicators and viruses. Results of the study showed fifty percent of the soil samples tested contained faecal coliforms. This source of contamination coupled with the widespread existence of biofilms within water distribution systems which may provide shelter and a platform for such pathogenic bacteria and viruses to multiply, highlights the significant risk to water quality posed by the ingress of external groundwater and other materials into the potable water supply.

Fig. 1. Leaking sewer pipe next to a leaking water pipe (Karim et al., 2003)

A striking example of a potential external contaminant source is shown in Fig. 1 which shows a failed sewer pipe above a leaking mains water pipe, a clear illustration of the coexistence of contaminant source and pathway.