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Modelling and flow conditioning to manage discolouration in trunk mains

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Abstract

This paper presents predictive discolouration modelling and subsequent field trial results for a cast iron trunk main network. This enabled a UK water company to propose an *'operational flow conditioning'* maintenance plan that reduces discolouration risk, improves network resilience and asset condition and yet does not require the trunk main to be decommissioned for invasive cleaning. This represents substantial time and cost benefits. Pre-and-post trial turbidity monitoring data is also presented which identified a daily flux of material, a factor in the regeneration of material layers that have been shown to cause discolouration when mobilised. Additional data detecting the occurrence of pressure transients is also presented, a possible cause of contaminant ingress and asset failure.

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1. Introduction

Due to a legacy of discolouration incidents following operational activities associated with trunk mains, increasing regulatory attention and the potential high consequences (large populations exposed), UK water companies have tended to shun trunk main operations for fear of consequences. In particular activities that result in increased flows are avoided, demonstrating the inherent understanding that discolouration is often hydraulically driven (Husband and Boxall, 2011). When increased flow through a trunk main is necessary (such as due to

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increased demand or source water changes), or unacceptable discolouration risk is identified, trunk mains have typically been taken out of service to undergo invasive cleaning. Although this may achieve good results in terms of risk reduction, the process is disruptive, requires specialist teams and tools, discolouration risk may be increased elsewhere as network settings are altered to re-allocate demand, and ultimately the cost is usually high.

Critically with discolouration material now known to continuously and ubiquitously regenerate throughout networks, any cleaning is seen to be of finite benefit (Vreeburg et al., 2008, Husband and Boxall, 2011). This leads to questions about the longer term cost effectiveness and sustainability of one off invasive cleaning strategies. As an alternative the PODDS conditioning strategy facilitates in-service cleaning by pro-actively managing incremental increases in flow. With no specialist tools required and the ability to be integrated as part of a standard and regular maintenance procedure involving no service disruption, discolouration material can be removed and the main conditioned to accept higher flows at little cost.

The PODDS approach to managing discolouration risk is founded on a number of well documented observations. Firstly, material responsible for causing discolouration is particulate in nature, typically around 10 μm (Gauthier et al., 2001, Seth et al., 2004), so unless systems exhibit very low flows for prolonged periods, gravitational sedimentation is not a dominant factor describing material behaviour (Boxall et al., 2001). Secondly that this particulate material is ubiquitously present at low background concentrations in treated water and as it passes through the network it accumulates as cohesive layers on all boundary surfaces (van Thienen et al., 2011). Water quality, or the concentration of material such as iron and manganese, appears to directly influence the rate at which these material layers develop (Husband et al., 2008). Improvements in treatment processes are therefore capable of reducing the development rate and so potential discolouration risk, but even ultra-filtered water has been shown not to eliminate layer development (Vreeburg et al., 2008). At some point a trade-off between capital spend on improved treatment and maintenance of distribution systems needs to be achieved. Other sources of material, such as resulting from contaminant ingress or the presence of corroding iron pipes and fittings, can also exacerbate the rate of layer development.

The PODDS model describes the rapid mobilisation of material accumulated at the pipe wall into the bulk fluid through consideration of a force balance at the boundary between cohesive material layers and the shear stress forces generated by the system hydraulics (Boxall et al., 2001). The model has been widely verified to successfully simulate discolouration responses in distribution networks (Boxall and Saul, 2005). For optimal simulation, site specific calibration of empirical model parameters is desirable. However, transfer of parameters has been successfully demonstrated in systems of similar pipe properties and supply water source (Husband and Boxall, 2010).

This paper details how the PODDS model and concept was applied to manage a cast iron trunk main system in the UK. The work is described in five stages. The PODDS model was initially used to predict the *discolouration risk* should an extreme flow event occur, such as likely following a burst. *Flow conditioning* modelling was then undertaken to determine flow increase steps that would be sufficient to mobilise material layers. This would effectively clean the pipe, but in a managed fashion so that bulk water quality would remain to acceptable standards throughout the process. The water company could then use this information to justify regulatory maintenance plans. Of note is that no relevant turbidity data or model parameter values previously existed for CI trunk mains. Model simulations were therefore based on existing parameter sets transferred from lined steel trunk mains. Prior to any maintenance work being undertaken, a *controlled flow trial* was then conducted on an upstream pipe section where the flow could be isolated from supply. This enabled *empirical calibration* of the PODDS model to this network and verification of the initial predictive and flow conditioning modelling. With intensive monitoring, this trial also collected valuable additional *operational* data. This included the detection of pressure transients, highlighting a possibility of contaminant ingress and increased risk of asset failure (LeChevalier et al., 2003, Collins et al., 2012).

2. Site Details and Predictive PODDS Modelling

2.1 Site details

The trunk main network investigated is centrally located in the UK and comprises just over 5 km of two