A Framework for the Minimization of Greenhouse Gas Emissions Associated with Water Distribution Systems Considering the Time-Dependency of Emissions Factors Associated with the Generation of Electricity

by
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Abstract

While water distribution systems (WDSs) form an integral part of modern cities, it is desirable to minimize the considerable costs that can be associated with their design and pumping operations. However, WDSs are complex systems and complete enumeration of all possible alternative solutions as a way of minimizing costs is generally not possible. As such, formal optimization algorithms have become a popular way to minimize the cost of WDSs within reasonable computational timeframes. Another important objective, minimizing the environmental impact of WDSs, has only more recently been considered. Human-induced climate change caused by greenhouse gas (GHG) emissions has become one of the most significant problems faced by human-kind. Water distribution systems contribute to the release of GHG emissions through both their design/construction and pumping operations.

When electricity used for pumping purposes is generated by fossil fuel generation sources, a significant amount of GHG emissions can be released over the project life of a WDS. This occurs to the extent where the majority of GHG emissions can be associated with electricity consumed for pumping purposes. However, within the literature considering the minimization of costs and GHG emissions associated with WDSs, most research has focused on design optimization, with less consideration being given to the pumping operations of a WDS. Therefore, there remains a need to consider the important aspects of pumping operations so that their associated costs and GHG emissions can be evaluated with the same level of accuracy as those associated with the design of a WDS. Consequently, this research incorporates the elements that are necessary to accurately evaluate costs and GHG

emissions associated with the pumping operations of WDS into a single framework for the minimization of costs and GHG emissions.

The major research contributions are presented in four journal publications. Firstly, the water distribution cost-emissions nexus (WCEN) conceptual framework is presented, which represents the nexus of elements required to accurately model and evaluate costs and GHG emissions when optimizing the design and pumping operation of a WDS. Secondly, in order to facilitate the practical application of these concepts, the WCEN computational software framework, which combines hydraulic simulation with multi-objective heuristic optimization, is presented. In particular, the WCEN computational software framework allows the design and pumping operations of a WDS to be optimized while considering both the short and long-term time-dependency of operational conditions, such as emissions factors associated with electricity generation, of which generally only average values have been considered. Thirdly, a methodology for calculating time-dependent emissions factors from electricity generation data is presented. Finally, a study on the effect of water storage tank size on the optimal design and pumping operations of a WDS is presented. While other design parameters can affect the costs and GHG emissions of WDS, storage tank size has been given little consideration in the past, especially when the time-dependency of emissions factors is also considered. It is hoped that this research will lead to the greater consideration of minimizing both costs and GHG emissions when developing designs and pumping operational management strategies for WDSs in the real world.

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Statement of Originality

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A list of works contained within this thesis is given in Section 6.3.

Signed:……………………………………...…Date:………………….

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