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Development of an integrated simulation model for treatment and distribution of reclaimed water

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Abstract

Research is currently being conducted as part of the AQUAREC project, with the objective being the development and validation of design principles for water reuse systems. To achieve the project objective, simulation and optimisation software for integrated water reuse systems need to be developed. A water reuse system is likely to have many possible design options: type and degree of treatment, number and location of treatment plants, number and location of pumps/pumping stations, number, size and location of storage tanks, layout and size of distribution pipe network. These elements are all linked, to give multiple interactions and a very large number of design combinations. A hydraulic/process simulation model has been developed and is described, which will be used in combination with an integrated optimisation engine to allow a range of design possibilities to be explored. The model includes a computational module for wastewater treatment trains, a computational/optimisation module for reclaimed water distribution system, and a knowledge base. The computational modules are used to calculate the performance of user-defined reuse system alternatives, utilizing the information contained in the knowledge base that includes rules for generation of treatment trains, design, cost and evaluation criteria information.

Keywords: Decision support; Simulation; Optimisation; Water reuse

1. Introduction

Reclaimed water projects typically include construction of new or upgrades to a municipality's treatment systems to treat wastewater to the required quality level, and construction of distribution systems for reclaimed water. A water reuse system is likely to have many possible design options: type and degree of treatment, number

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and location of treatment plants, number and location of pumps/pumping stations, number, size and location of storage tanks, layout and size of distribution pipe network. These elements are all linked to give multiple interactions and a very large number of design combinations, even for apparently small systems. The complexity associated with planning of water reuse schemes is therefore very high due to a very large number of design combinations possible, and establishes the need for use of a decision support systems (DSS) to aid in the planning process.

A DSS for Water Treatment for Reuse with Network Distribution (WTRNet) is currently being developed within the AQUAREC project on Integrated Concepts for Reuse of Upgraded Wastewater, under the Fifth European Community Framework Programme. The DSS provides an integrated framework for evaluation and optimisation of treatment and distribution aspects of water reuse, and will be used to achieve the ultimate project aim of the development the design principles for water reuse systems. This paper describes the current progress on the development of the DSS — the simulation and optimisation models for water reuse systems — and discusses the direction in which the development is heading. This is preceded by a brief summary of a literature review of DSS in water reuse, covering the treatment and distribution aspects of reclaimed water.

2. Review of DSS for water reuse

2.1. Generation and screening of treatment trains

The number of treatment processes used to treat wastewater has been steadily growing. This is particularly true for advanced treatment technologies capable of treating wastewater to a degree of quality appropriate for reuse, making the selection of the most suitable sequence of processes (treatment train) for any potential reuse situation more complex. The challenges experienced by planners and designers of water reuse systems include deciding on suitable treatment trains from a large number of unit process combinations [1] as well as handling of multiple objectives that treatment systems need to satisfy [2].

The selection and design of appropriate treatment alternatives for water reclamation can be considered in a three-stage process involving the selection of alternatives, pilot-plant studies and selection of a preferred alternative for detailed design [3]. The focus here is on the first stage, the evaluation of performance and cost of a number of treatment alternatives to select the most appropriate ones for more detailed evaluation. The tasks involved in this stage can further be divided into: selection of unit processes, synthesis of treatment trains, evaluation and screening of synthesised treatment trains, and selection of an optimal (or near optimal) treatment train [4]. The development of the simulation model focused on the first three of these tasks, while the integrated optimisation component is currently under development and will be added to WTRNet in the future.

Models developed in the past for synthesis of treatment trains used a variety of methodologies to generate and screen unit process combinations. Examples of methodologies used for wastewater treatment (with and without reuse) include enumeration techniques [5,6], Monte Carlo simulation [1], heuristic search [7,8], and modelling to generate alternatives [9]. A detailed overview of these methodologies is presented by Dinesh [4]. The same author presented a comprehensive approach for evaluating and optimising treatment alternatives for wastewater reuse using genetic algorithm (GA) in a DSS called MOSTWATER. Another tool developed to assist planners in evaluating treatment trains for wastewater reclamation, WAWTTAR, described by Finney and Gerheart [10], is intended primarily for developing countries, and it does not include an optimisation routine. Both of these models aid the user in evaluation of treatment trains from unit