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User-Friendly Decision Support Tool for the Selection of Wastewater Treatment Technologies for the Removal of Emerging Contaminants

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EXTENDED ABSTRACT

Introduction

Insufficient water resources and water quality deterioration represent widespread issues around the globe. The main factors triggering these issues are: (i) population growth, (ii) improving standard of living, (iii) contamination of fresh water resources, (iv) frequent droughts caused by extreme global weather patterns, and (v) uneven distribution of water resources [1]. Therefore, water reuse, as part of sustainable water management, is considered a suitable option to increase water supply [2] and alleviate pressures on the existing water sources. In the past, the selection and design of Wastewater Treatment (WWT) technologies were based on each technology's performance in terms of a number of objectives (e.g. capital and operational costs and skill requirement) and with respect to the removal of conventional contaminants such as: Biochemical Oxygen Demand (BOD) and Total Nitrogen (TN). However, recently a growing number emerging contaminants (ECs) have been detected in the aquatic environment. ECs, often defined as naturally occurring, synthetic or anthropogenic chemicals/substances which are not regularly monitored, are divided into the following classes: (i) pharmaceuticals, (ii) personal care products, and (iii) endocrine disruptors [3], [4]. The dominant pathway of ECs to enter the aquatic environment is through the effluent of WWT plants [3], [5]. This is due to the fact that existing WWT plants were designed to remove conventional contaminants [6]. Therefore, in the process of selecting and/or designing any WWT technologies, the occurrence and removal of CECs should also be taken into consideration. To this end, in this study we developed a user-friendly Decision Support Tool (DST) to facilitate decision makers with the complex process of selecting optimal WWT solutions incorporating all stages of treatment (namely: preliminary, primary, secondary and tertiary treatment), keeping in view the end users' preferences and needs and emerging contaminants removal requirements.

Methodology

The DST developed in this study implemented enumeration and Multi Criteria Decision Analysis (MCDA) techniques to generate optimal WWT solutions. To evaluate the performance of each solution with respect to different objectives and criteria and to determine their efficiency at removing both conventional contaminants and CECs in different water reuse scenarios. The tool is comprised of four components: **(i) Database (DB)**: this includes the information related to different WWT processes reported in the literature, available on the international market and tested innovations. DB includes 11 structured sections to accommodate treatment technologies for conventional pollutants, ECs, nutrient recovery, energy recovery and sludge processing. **(ii) Graphical User-Interface (GUI)**: this was developed using a C++ Builder and RAD STUDIO, a powerful GUI application development platform. The primary focus of the GUI is to allow users to input necessary information to run the DST. Through the user interface, the end users will be able to input the context/scenario information (e.g. volume and characteristics of wastewater including ECs loads, wastewater generation profile, intended end use of treated wastewater), select optimisation constraints and objectives, assign weights and select/deselect different criteria for criteria evaluation and decide the solution generation/optimisation method. **(iii) Optimal Solution Generator (OSG)**: this was done through the development of computational code that integrates the DB and the GUI and couples them with an Enumeration Algorithm. This algorithm systematically generates every possible solution and guarantees the identification of all feasible solutions. The algorithm excludes part of the search space based on the treatment train synthesis rules and technology compatibility. **(iv) Solution Evaluator (SE)**: OSG-generated solutions are further evaluated with respect to different criteria. This prioritises the solutions that have the shortest distance from the positive ideal solution based on MCDA approaches. SE facilitates visualisation of each identified/generated solution's performance with respect to different objectives as well as the efficiency of ECs removal though a range of data presentation and synthesis options including web diagrams and stacked charts (see Figure 1). It is noteworthy that the tool evaluates the performance of each solution for removing 15 ECs : (i) Amoxicillin; (ii) Atrazine; (iii) Bisphenol A.; (iv) Caffeine; (v) Carbamazepine; (vi) Ciprofloxacin; (vii) Dichlorodiphenyl; (viii) Diclofenac; (ix) Dimethyl Ph.; (x) Endosulfan; (xi) Ibuprofen; (xii) Naproxen; (xiii) Nonylphenol; (xiv) Norfloxacin; and (xv) Sulfamethoxazole.

Results

The tool is applied to a number of scenarios in order to identify optimal WWT solutions and to assess technology potential for different wastewater reuse applications, scales and contaminants of concern. To achieve this, different scenario sets with various parameters/variables are constructed. For each scenario, the enumeration algorithm is applied to accommodate the generation of all feasible solutions; the generated solutions are then further assessed by MCDA. Figure 1 illustrates an example of results for a scenario considering 6 objectives; 6 criteria and one EC (Carbamazepine). In this particular scenario, over 100 feasible solutions were identified; here in Figure 1, only the best six are illustrated.

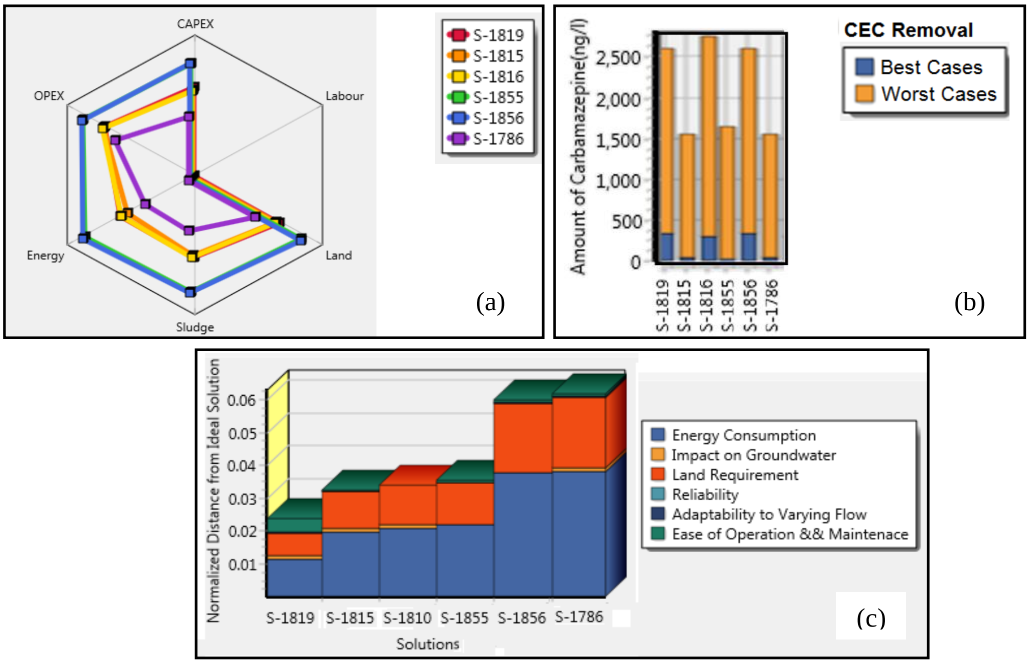

Figure 1. Performance of the optimal WWT trains in an example scenario set with respect to: (a) user selected objectives (spider-web chart); (b) removal of Carbamazepine as the contaminant of emerging concern in this scenario; and (c) MCDA criteria (criteria contribution stacked chart)

Conclusions

The aim of this research was to develop a user friendly multi-criteria based DST capable of automatically generating optimal WWT solutions for different water reuse scenarios and identifying the best solutions for the removal of ECs. The tool is being applied to different scenarios in different contexts and results will be discussed with a view to illustrate the various functionalities the DST offers and how these contribute towards informed decision making, in which the users (decision makers) play the main role in the identification of the optimal solutions. In such a DST, the availability of accurate data on various technological and associated sustainability aspects, as well as the context related data (provided by the user) would enhance the confidence in the implementation of DST results.

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