Theme: A. Technologies for Water Management and Monitoring
Subtheme: A5. Optimization Techniques and Their Application

Development and Application of a User-Friendly Decision Support Tool for Optimization of Wastewater Treatment Technologies in India

Seyed M. K. Sadr [1], Matthew B. Johns[1], Fayyaz A. Memon [1], Mark Morley[1], Dragan A. Savić[1]

[1] Centre for Water Systems, College of Engineering, Mathematics and Physical Sciences, Harrison Building, North Park Road, University of Exeter, Exeter, Devon, EX4 4QF, UK

Corresponding author: M.B.Johns@exeter.ac.uk

Abstract. The selection of suitable wastewater treatment solutions is a complex problem that requires the careful consideration of many factors. With water at a premium and water consumption increasing, India is facing a challenging time ahead, requiring effective water treatment solutions. The Wastewater Decision Support Optimiser (WiSDOM) presented here is a user-friendly software package designed to aid in the formulation and configuration of wastewater systems in developing countries such as India. WiSDOM employees advanced multi-objective optimisation and decision analysis techniques to identify optimal wastewater treatment options. It has been demonstrated that WiSDOM can adapt to a wide array of scenarios, considering a range of contributing factors (technical, environmental, economic and social), enabling an engineer to make more informed decisions.

Keywords: Decision support systems, Multi criteria analysis, Multi objective optimization, Wastewater management in India, Water reuse applications,

1   Introduction

India represents about 1/6th of the world population but accounts for 1/25th of water resources of the world [1]. Due to population growth, the water demand is expected to increase while, per capita average annual water availability has been reducing from 5177 m3 in 1951 to 1588 m3 in 2010 [2]. In addition, due to rapid urbanisation and growth in the quality of life, the wastewater generation has significantly increased and expected to increase further [3]. Therefore, there are two major challenges in India in the coming years: 1) reduced fresh water availability and 2) increased wastewater generation. However, irrigation accounts for about 85 per cent of water usage in India and the majority of this amount could be potentially managed by treated wastewater, therefore, water reuse would be a promising solution to overcome water related challenges in India. The selection of suitable wastewater treatment (WWT) solutions is a complex process [4] where several factors need to be considered, this is especially the case in India where a wide variety of socio-economic and environmental contexts exist. This results in the need to include a range of decision objectives and criteria e.g. capital, operational and maintenance costs, energy consumption, chemical requirement, land requirement, and reliability. This paper describes the development and application of the WaStewater Decision support OptiMiser (WiSDOM), a user friendly decision support tool designed to make the generation and selection of highly optimal WWT configurations more accessible for different stakeholders including engineers and local authorities.

2   Methodology

2.1   WiSDOM Tool Description

WiSDOM is a user friendly decision support tool that employs Multi-Objective Optimisation (MOO) techniques and Multi Criteria Decision Analysis (MCDA) to generate optimal WWT solutions.

WISDOM has been developed as part of the SARASWATI project, funded by the European Commission (FP7) and the Government of India. The tool consists of multiple components each contributing to the functionality of the tool. At the core of the tool is the **technology library**; a database containing detailed information on over 40 unit processes and 10 packaged WWT systems. Each unit process and treatment package has detailed characterisation data including methods for evaluating metrics such as required capital investment, operational costs, energy usage, sludge production, and water contaminant removal performance. The technology library database is heavily utilised in the optimisation engine to evaluate candidate treatment train solutions. The **optimisation engine** utilises a Multi-Objective Genetic Algorithm (MOGA) to generate optimal WWT train solutions. The tool includes two MOGAs; the Non-Dominated Sorting Genetic Algorithm-II (NSGA-II) and the Omni-Optimiser (Omni-GA) giving the user the ability to choose to use either. The selected MOGA uses context information provided by the user and unit process data from the technology library database to evolve optimal treatment train solutions based on the users chosen treatment train configuration. To simplify the selection of a suitable solution, Multi-Criteria Decision Analysis (**MCDA**) is then performed on the resultant solution set generated by the MOGA. The MCA employs a Compromise Programming method to evaluate and rank the MOGA solutions based on criterion weighting provided by the user, resulting in the prioritisation of solutions which reflect the user's preferences. The user engages with the tool through a **Graphical User Interface** which is designed to be easy to use whilst providing the user with extensive control over the design and optimisation process. The user interface consists of several tabs (Table 1) which guide the user through the necessary steps to perform an optimisation and evaluate WWT trains for their specific contexts.

Table 1 The main tabs of the WiSDOM Tool and their main features

Main tabs	Description (features)
Welcome & user information	This tab includes a description of the purpose and functionality of the tool. It is also used to gather information on the user, e.g., name, position and level of expertise.
Context definition	This is where the user provides information on the context of their WWT project; e.g. Name and location of the project, population to be served, wastewater production, land and budget restrictions and intended use of the treated water.
Raw wastewater information	This tab requires the user to provide information of the influent wastewater stream; e.g. contaminants levels, expected daily (or hourly pattern of) volume of wastewater, etc.
Objectives & criteria selection	This tab provides the user with control over the optimisation engine. The first section of this page allows the user to choose which objectives the MOGA will use to optimise the proposed WWT train. In the next section, the user has control over different GA parameters; e.g. MOGA algorithm types (NSGA-II or Omni-GA), run length, population size, crossover rate and mutation rate. The user also can select/deselect unit processes and chose MCDA criteria and their weights for the evaluation process.
MOGA solutions	The MOGA Solution tab provides the user with the ability to initialise and run the MOGA. Upon completion, the user is presented with the final population of treatment train solutions and scatter plots are displayed showing the trade-off between the different objectives for all final solutions. The user can also generate radar charts from the population of results, allowing the direct visual comparison between individual solutions in terms of the chosen objectives and contaminant levels.
MCDA solutions	The MCDA is run on the final population of solutions obtained by the MOGA based on the evaluation. This tab contains a table of MCDA solution rankings which displays 50 of the highest ranked treatment train solutions. Each solution can be selected to view a detailed breakdown, including objective and contaminant removal figures for each individual unit process within the treatment train. Also, a stacked bar chart is designed to illustrate the performance of each solution in terms of the evaluation criteria selected.

2.2   Tool application scenarios

WiSDOM has been applied and tested by running several hypothetical scenarios of WWT in India. The aim was to test the functionality of the tool, identify different treatment solutions (e.g. technology combinations) and therefore assess their potential for different possible contexts/scenarios applicable in different parts of India. Based on the necessity of WWT in India, several scenario sets have been defined. Here we present the results of the following scenario set:

2.2.1   Technology potential for different development scenarios

This set of scenarios investigates the impact of development constraints on the technology potential, and is divided into the following three cases: **(a)** Technology potential for a large-scale metropolitan area with a population of 500,000 inhabitants and limited land availability, **(b)** Technology potential for a medium-size settlement, with a population of 8,500 inhabitants, facing water scarcity for irrigation and landscaping, and **(c)** Technology potential for a small remote area with a population of 200 inhabitants and limited availability of skilled labour.

3   Results and Discussion

The defined set of scenarios assess the technology potential of WiSDOM based on variations in assumptions/parameters; this aims to fully explore the tool's ability to produce optimal WWT configurations for a various situations. A cross-section of eight solutions are presented from the generated population of results. For each scenario, the following parameters remain constant. NSGA-II is applied with a population size of 50, a cross-over rate of 0.85 and mutation rate of 0.15. The optimisation is run for 500 generations before the final population achieved. The results obtained from the tool and the corresponding discussions are provided below:

3.1   Technology potential for different development scenarios

This scenario set, as an example, uses Maharashtra State. Its capital city is Mumbai, and is located in the western region of India. In this state, there are some metropolitan areas such as Mumbai and Pune with urban, semi urban and rural areas. Therefore, different levels of urban development have been considered as scenarios. The main focus of the first scenario **(a)** is on the technology potential of a metropolitan area with a population of 500,000 inhabitants with very limited land availability. The treated wastewater is aimed to be reused for toilet flushing and fire protection purposes. The second scenario **(b)** describes a medium sized settlement with a population of 8,500 inhabitants with a focus on technology to address water scarcity with horticultural irrigation as the intended water reuse option. The final scenario **(c)** presents a small remote rural area with very limited availability of skilled labour for system operation and maintenance. The intended use of treated wastewater is agricultural irrigation. The results shown in Figure 1 reveal that the optimal composite technologies (treatment trains), selected by the tool in these scenarios (a, b and c), are acceptable since they are generally performing well with respect to all four selected objectives (e.g. CAPEX, OPEX, Land Requirement, and Labour Requirement). Results of the first case study (Scenario a) show that the performances of optimal solutions S-309062 and S-309132 outperform other optimal solutions (Figure 1 (a-1) and (a-2)). In Scenarios 4b and 4c, on the other hand, skilled labour and reliability of systems are more critical in comparison with land requirement (Figure 1 (b-1), (b-2), (c-1) and (c-2)). Therefore there are several natural treatment systems among the optimal solutions in Scenario b, and a number of automated systems (i.e. systems with minimum need of operation and maintenance staff) in Scenario c. This shows the tool is responsive to variation in user preferences demonstrating flexibility for a range of different scenarios.
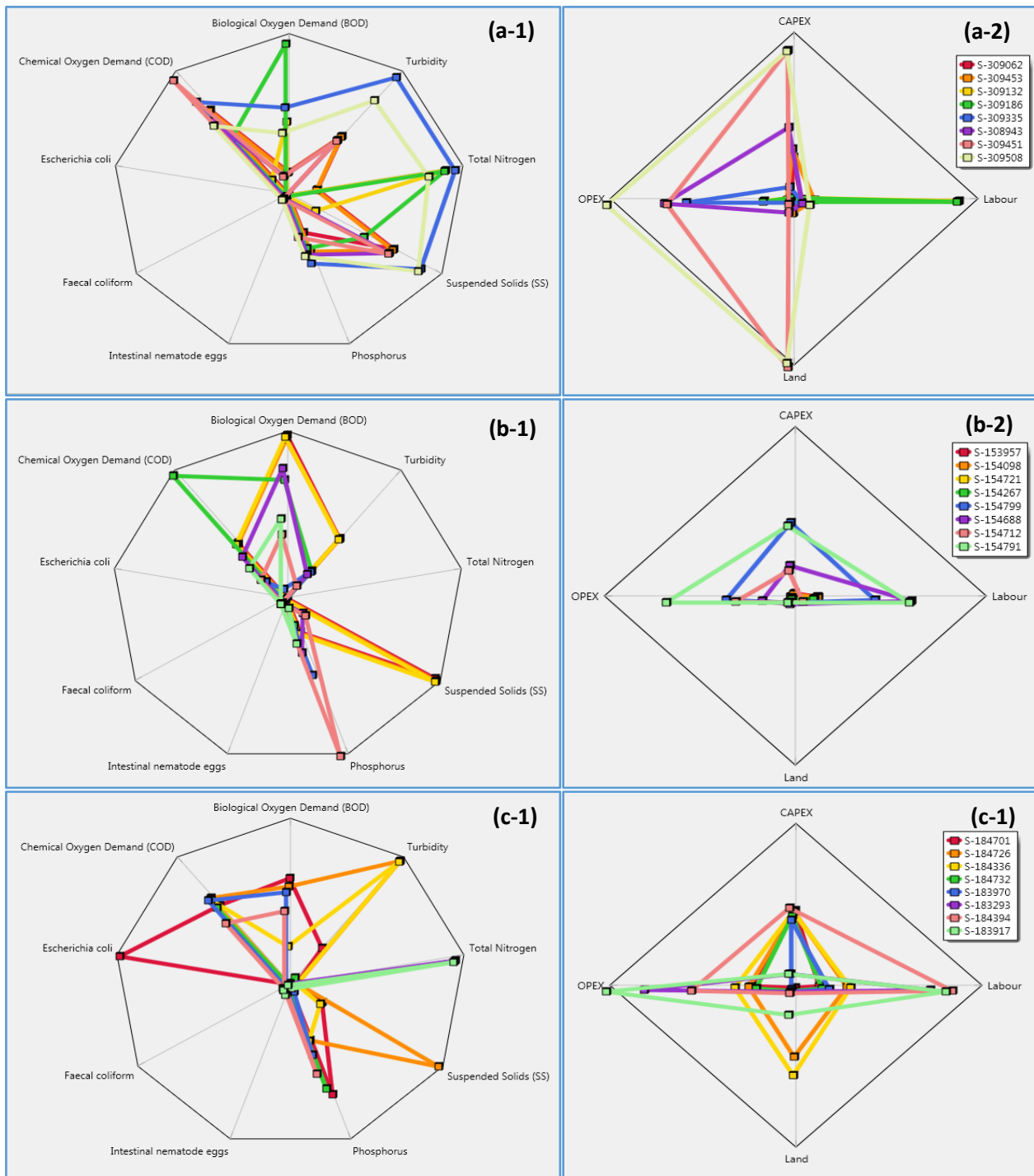
Figure 1 Performance of the optimal WWT trains in this scenario set: (a-1) contaminant removal in Scenario a; (a-2) MOO objectives in Scenario a; (b-1) contaminant removal in Scenario b; (b-2) MOO objectives in Scenario b; (c-1) contaminant removal in Scenario c; and (c-2) MOO objectives in Scenario c

4   Conclusion

Technology potential varies with the context within which it is applied. The WiSDOM tool results suggest several optimal solutions for each scenario investigated. A selection of these potential solutions was discussed above with respect to several performance indicators. This selection is very much influenced by selected optimisation objectives, relative weights assigned to different selection criteria, method of optimisation and input data quality. The availability of accurate data on various

technological and associated sustainability aspects will enhance WiSDOM utilisation potential. The tool in its current form can facilitate decision making and could form a basis for negotiation between different stakeholders and evaluate the impact of their preferences and constraints on the identification of potential solutions. The tool application can help to shortlist the most promising solutions before the detailed investigation and design of a solution commences.

Reference

[1] R. Kaur, S. P. Wani, A. K. Singh, and K. Lal, 'Wastewater production, treatment and use in India.', presented at the The 2nd Regional Workshop on Safe Use of Wastewater in Agriculture, India, 2012.

[2] CWC., 'Water & Related statistics', Water Planning & Project Wing, CWC, India, 2010.

[3] D. Kumar, S. K. Sharma, and S. R. Asolekar, 'Significance of incorporating constructed wetlands to enhance reuse of treated wastewater in India', in *Natural Water Treatment Systems for Safe and Sustainable Water Supply in the Indian Context*, London, UK: IWA Publishing, 2016, pp. 161–176.

[4] F. A. Memon *et al.*, 'Development of a stakeholders informed decision support system for optioneering the treatment and reuse of wastewater', in *International Conference On Innovations in Sustainable Water and Wastewater Treatment Systems (ISWATS)*, Pune, India, 2016.