Designing Sustainable Wastewater Systems

Generating Design Alternatives

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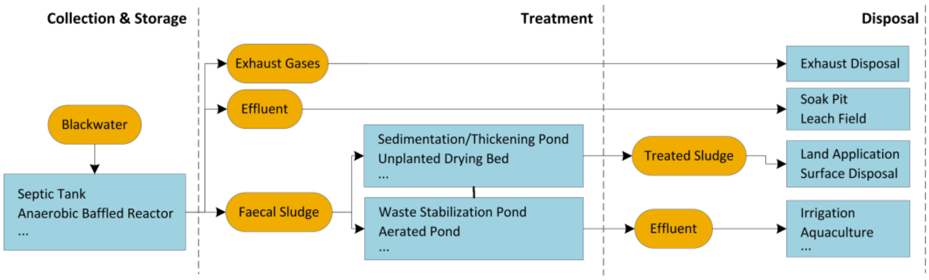
1 Introduction

The majority of water and wastewater infrastructures in the industrialized world will require retrofitting and replacement in the near future. Furthermore, there is a growing need for new infrastructure in developing countries. Growing environmental and energy concerns in combination with the challenges involved in securing the quality and quantity of water heighten the urgency of the issue [1-3]. Thus, identifying sustainable solutions requires the simultaneous consideration of economic, ecological and social goals. The challenge is considerable; it is a context-dependent multi-dimensional, multi-objective decision problem in which competing objectives must be identified and trade-offs made [4-7]. The complexities of the field, in combination with high liability risks and considerable fixed costs, have resulted in slow uptake of innovations. A considerable challenge facing decision makers relates to the fact that it is extremely time consuming to gain an overview of new and emerging wastewater technologies, as the field is both dynamic and tenaciously fragmented [8-10].

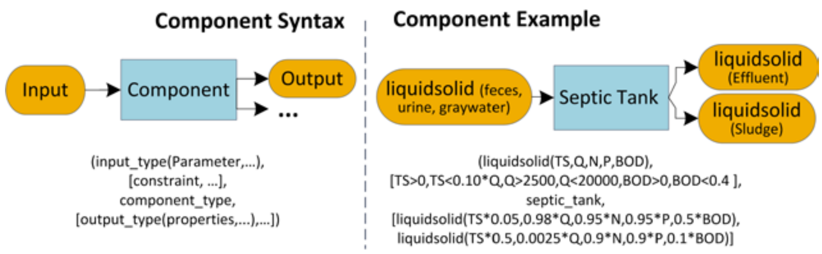
Clearly, there is a need for easily accessible, synthesized information to support decision making for cost-effective, sound and sustainable wastewater management practices. Researchers have laid the groundwork for developing computational support tools for designing and optimizing alternative wastewater systems [e.g. 11, 12]; and our work builds upon these in order to foster more sustainable and wise planning. We are developing a decision-support system (DSS) to aid decision makers, engineers and related constituents in identifying and selecting alternative wastewater systems which balance environmental, economic and social needs. Our DSS consists of three different modules: 1) constructing a database and ontology about wastewater components, technologies and processes, 2) developing a tool capable of generating possible alternative wastewater treatment systems, and 3) a preference-elicitation method for guiding decision-making and the selection of ideal alternatives.

2 Methods

Our focus here is on the development of Module 2. We draw from the Compendium of Sanitation Systems and Technologies [13] as an example, to identify combinations of components of a rural wastewater system for use in developing regions. Figure 1 depicts a simplified version of one system presented in the Compendium. The systems presented in the Compendium were created manually, whereas our goal is to develop a method for generating alternatives dynamically. In doing so, we can provide decision makers and engineers with a tool to compare alternatives and aid the design more sustainable systems.



Our model uses the wastewater components listed in the Compendium, and from them, automates the creation of systems by searching for all combinations of these components based on a formal specification of input/output constraints. Maurer et al. [12] uses a similar approach, but relies upon a compatibility matrix produced a priori to derive systems. Our model extends this approach by using constraint based logic programming [see 14, 15]to generate alternatives based on the functions of components and their quantitative input/output properties. We define a component (e.g. septic tank, biogas reactor) as a technology/method/process which requires one input product and can produce a number of output products. A product is described by a set of properties relevant to the kinds of outcomes and measures that are important for treatment. In Figure 2 an input product has the following parameters: Total Solids (TS), Flow (Q), Nitrogen, Phosphorus and Biological Oxygen Demand (BOD). A component which has no output represents a method of use or disposal of its input. Figure 2 depicts a conceptual model (left) and an example (right) of inputs, a component and its outputs, as well as, the associated syntax of a component.



3 Conclusion

We have created a component schema and adapted 24 of the components from the Compendium into our model. From these we can generate thousands of alternatives that satisfy constraints such as effluent quality, flow (volume per unit time) and proportion of solids. We are currently working with experts to improve the realism of our system through an accurate definition of the functions and constraints of different components, while also growing the set of components in order to generate a larger number of alternatives. In regards to the project umbrella, this Module (#2) is intended to feed into Module #3; where additional constraints and preference elicitation methods are used to further reduce the number of alternatives to a set of solutions meeting the user's goals. Ultimately, we intend to expand Module #2 to include urban wastewater systems, and in general, to expand the functionality and practicality.

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