EDUCATIONAL TOOL FOR DESIGN OF WASTEWATER TREATMENT AND WATER REUSE SYSTEMS

Yuri Avramenko and Andrzej Kraslawski*
Lappeenranta University of Technology
P.O. Box 20, FIN-53851 Lappeenranta, Finland

Abstract

There is an astonishing lack of awareness among many technical service providers and environment practitioners with regard to the range of wastewater treatment methods and equipment available. The paper presents an effective training and reference tools focusing on wastewater treatment and water reuse systems. The tool is composed of four parts: reference system, case base manager, treatment adviser, and process visualizer. Reference system manages all background knowledge existing in the tool. Case study manager performs the retrieval of the most similar cases to the current problem from the case base containing the past designs of wastewater treatment systems. Treatment adviser is able to generate a simple sequence of treatment methods for wastewater. Process visualizer has the ability to construct the treatment sequences and to represent them graphically.

Keywords

Design of wastewater treatment systems, Case-based reasoning, Training and education.

Introduction

The design of wastewater treatment (WWT) and water reuse (WR) systems is a demanding task for the engineers. Usually the task facing an engineer is to determine the levels of treatment that must be achieved and a sequence of methods that can be used to remove or to modify the constituents found in wastewater in order to reduce the environmental impact and to meet ecological requirements. The solution of the this task requires the detailed analyses of local conditions and needs, application of scientific knowledge and engineering judgment based on past experience. Nowadays, with the increasing number of complex wastes that are the result of industrial operations, it is more than ever necessary for an engineer to review all the available methods, processes, systems and equipment in the light of demands and conditions, and to apply any single method or combination of them in the given situation. The reference tool that accumulates the most of the available knowledge in the filed in an easily accessible way would be of great interest to the engineers.

In addition, in many cases the wastewater problems are similar and they can be solved in similar way. A design engineer may meet a problem to determine the similar elements between a new problem and massive historical data; moreover, the similarities are often not noticeable. Therefore, the approach, which is able to find the similar past design situations, would be very helpful.

Very often there is an astonishing lack of awareness among many technical service providers and environment practitioners with regard to the range of wastewater treatment methods and equipment available. Moreover, the actual trend is to focus on equipment ignoring such essential factors as skills and training. In such situation, there is a need for effective training and reference tools focusing on wastewater treatment and water reuse systems. This work presents information technology based tool for educational purposes, with the special focus on study of real life situations. The objective of the work is to develop a sustainable tool for training on technologies for improved environment management.

* e-mail: Andrzej.Kraslawski@lut.fi

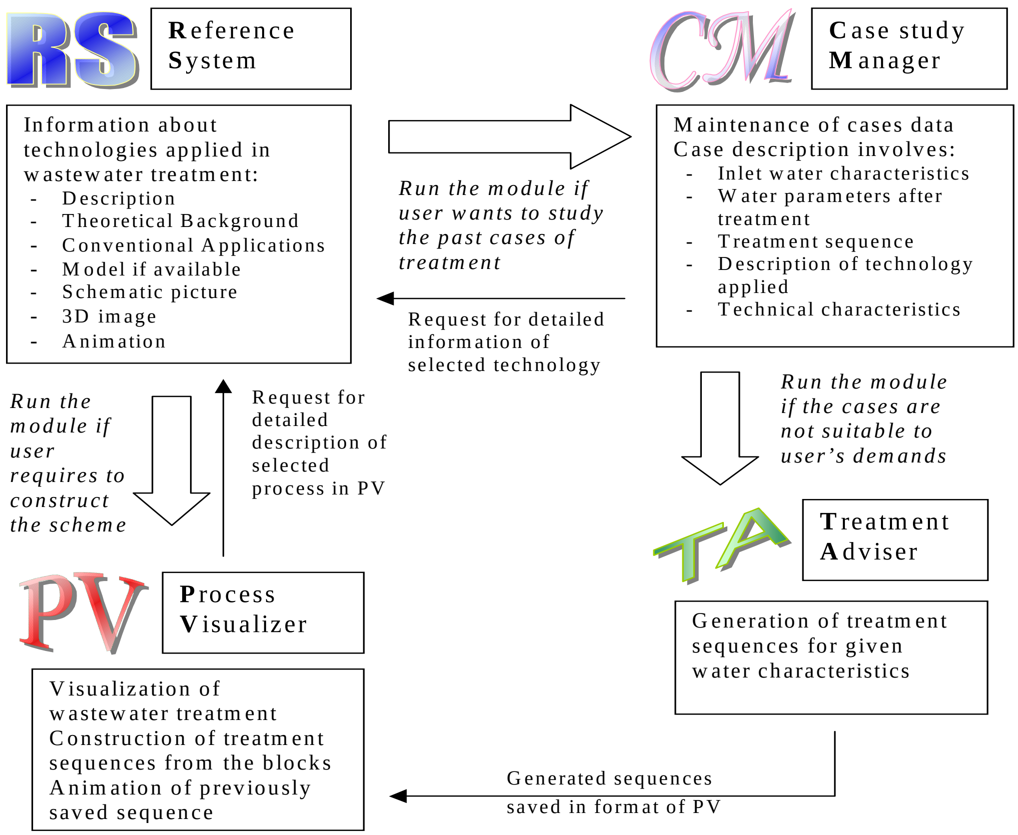

Figure 1. The architecture of educational tool

Overview of educational tool

The main function of educational tool is to provide knowledge on wastewater unit operations, fundamental understanding of the mechanism of wastewater treatment, and analysis of past design cases.

The tool is composed of four parts: reference system (RS), case base manager (CM), treatment adviser (TA), and process visualizer (PV). A schematic layout of the tool is shown in Fig.1.

Reference system contains all background knowledge existing in the tool. From RS the user can go to case study manager to learn the past situations of wastewater treatment and even search for the solution of the current situation. If acceptable solution cannot be found, the treatment adviser tries to generate a sequence of operations for removal constituents found in wastewater that is introduced by the user. Generated sequences can be visualized in the process of visualization. The visualization is required for the better understanding of the principles of wastewater treatment operations. The user can also build the treatment sequences from blocks by himself, utilizing the special drag and drop builder realized in the process visualizer. Each block corresponds to an operation of treatment.

Next, the components of the tool are described in details.

Reference system

The purpose of the reference system is to provide the user with comprehensive information of processes and operations used for wastewater treatment. In addition to general description, the system includes the theoretical background and the most popular applications of a treatment method. To illustrate the principles and the units used in the wastewater treatment, the system contains the schematic pictures, photographs, 3D images and animation of the corresponding operations. The animation provides the basic understanding of how the process is realized and it is very helpful in the learning process.

The models can perform simple calculations based on the balance equations; the external computing modules can be linked as well.

The individual methods are usually classified as physical operations, chemical and biological processes. But in the methods library of the reference system the unit operations and processes are grouped according to the level of the provided treatment. There are preliminary, primary, secondary, and advanced treatment methods presented in the library. The group of primary treatment contains mostly physical operation, such as screening, sedimentations, flotation. The secondary treatment group is represented exclusively by biological processes.

Each group can be expanded into subgroups. For example, the secondary treatment group (biological treatment) is divided into aerobic and anaerobic suspended growth methods, aerobic and anaerobic attached growth processes, and lagoon methods. Further, a subgroup is splitted into types of unit processes. An example of the specification of activated sludge process is shown in Fig. 2.

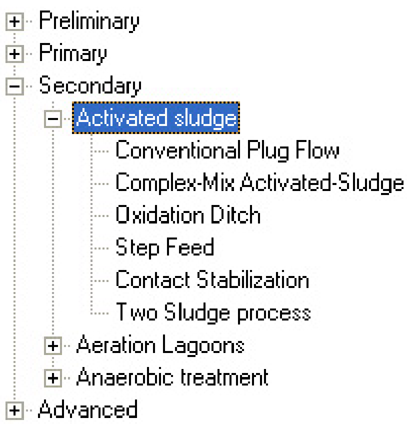

Figure 2. Activated sludge variations

Case Study Manager

The main task of case study manager (CM) is to accumulate the specific design experience contained in real life situations, and try to reuse it when solving new user's problems. CM performs the retrieval of the most similar cases to the current problem from the case base containing the past designs of WWT and WR systems.

Case-based Reasoning (CBR), which is utilised in CM, is based on the assumption that the similar problems have the similar solutions. The practice shows that often it is more efficient to solve a problem by starting with a solution of a previous, similar problem than to generate the entire solution from scratch. CBR deals with very specific data from the previous situations, and reuses results and experience to fit a new problem situation. A single case is composed of two parts: a problem and its solution. Several cases are collected in a set to build a case base.

In solving a current problem, there are retrieved a similar, past problem and its solution using a set of rules for measuring similarity between actual problem and those stored in case base. The representation of design cases requires various models because design content involves topological, geometric, and physical properties and relations between them. The descriptions of wastewater treatment problems are often incomplete and uncertain. There has been developed the special similarity concept that copes with the data represented in the different format (numeric, linguistic and hierarchical). There is applied object-oriented case representation that facilitates the retrieval procedure.

Applying CBR to design allows to avoid difficult, time-consuming acquisition and representation of design knowledge.

The representation of the design case includes description of water characteristics at inlet and outlet of the treatments system, type of industry, description of used technology, and technical parameters of treatment operations such as flow rate, energy consumption, cost of treatment etc (see Tab.1).

Table 1. Representation of wastewater treatment case

Section	Group	Subgroup	Example
Water features (before and after treatment)	***Suspended solids***	*Coarse solids*	grit, rag
		Fine solids	TSS
		Colloidal particles	gel
	Inorganic matter	*Nonmetallic*	pH, Chlorides, Alkalinity
		Metallic	Chromium, Copper, Lead
		Nutrients	Nitrogen, Phosphorous
	Organic matter	*Biodegradable compounds*	BOD
		Volatile organic compounds	Chlorinated organic solvents
		Individual compounds	Phenols, Aldehydes, surfactants
	Toxicity		
	Pathogen microorganism		
Type of industry			Textile, Rubber&Latex
Treatment sequence			Rubber trap, Anaerob. filter, Activated sludge, Settling
Description of technology			
Technical parameters of treatment operations			flowrate, treatment costs

The task of the case study manager is to retrieve and rank relevant cases for the current user's problem. Once relevant cases have been retrieved from the case base, the user can browse through them in order to select the most applicable ones for the current situation.

The case base manager provides facilities for reviewing, deleting, and editing existing WWT and WR cases, as well as possibilities for adding a new case.

Treatment adviser (TA) is started when the user is not satisfied with the suggested solution. TA generates a simple sequence of treatment methods for wastewater introduced by the user. This component of educational tool analyzes the influent water characteristics and selects, performing the original algorithm based on set theory, the methods of treatment. The algorithm of selection is based on the search among the water parameters, so-called harmful factors that have to be eliminated. The factors are determined by specific set of wastewater characteristics. For example, the phenol concentration in water above 50 mg/l and up to 500 mgl/l defines the harmful factor “Middle concentrated phenol”.

All harmful factors have to be removed from the wastewater stream. Each harmful factor can be treated by specific set or several sets of methods that are capable to remove the factor from wastewater. The stream may contain a number of harmful factors that can be processed by many sets of treatment methods. As a result of analysis, one or several treatment sequences are generated and then evaluated by economical and treatment efficiency criteria.

The generated sequence can be studied using reference system (theory, model). It also can be graphically illustrated in the process visualizer.

Visualization of treatment

The visualization is an important part of the educational process. The animation of processes illustrates the principles of treatments and provides the understating of the work of units involved in the wastewater management. An example of process visualization is presented in Fig. 3.

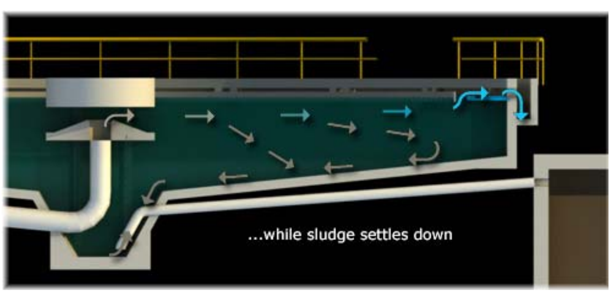

Figure 3.Visualiztion of settling tank.

Process visualizer has the ability to construct the treatment sequence from the blocks and makes the visualization of the result. The user can drag and drop the blocks located on the screen. Each one of these blocks represents a type of water processes or specific part of the process. Blocks can be linked one to each other according to internal restrictions, rules and locations of connection points. When two or more blocks have been connected, flow animation or process visualization occurs.

The constructed sequences can be saved into the file and restored in the next session. The detailed explanation of the process represented by the block can obtained by double clicking on the block – PV takes the user to RS at the position of selected process.

Conclusions

The presented educational tool is capable to satisfy the needs of many users: teachers of environmental engineering, the consultants who are seeking a solution to client’s problem, the engineers who would like to have an easy access to background knowledge, the students looking for the support to understand the wastewater problems.

The tool provides the additional value to the existing educational programs by integration of real-life applications with theoretical knowledge.

One of the main advantages of the educational tool is the visualization of operation involved in the wastewater treatment.

The presented educational tool can be used to the other applications like air pollution control and sludge management.

References

Nemerow N. L., Dasgupta A. (1991). Industrial and hazardous waste treatment. , Environmental Engineering Series, Van Nostrand Reihold, New York, 743 p.

Sanchez, M., U. Cortes, I. Roda, M. Poch., J. Lafuente, (1997) Learning and Adaptation in Wastewater Treatment Plants through Case-Based Reasoning, *Microcomp. in Civil Eng.*, **12** (4), pp. 251-266

Tchobanoglous, G., Burton F.L., Stensel H.D. (2003) Wastewater Engineering: treatment and reuse / Metcalf & Eddy, Inc. – 4th ed. 1820 p.

Ines S.F. Freitas, Carlos A.V. Costa, Rui A.R.Boaventura (2000). Conceptual Design of industrial wastewater treatment process: primary treatment. *Computers & Chemical Engineering* **24**. pp. 1725-1730.