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Educational training system for design of efficient water treatment

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The work presents training and reference computer system on wastewater treatment and efficient water reuse. The information system is a package of computer applications supplemented by data files, text notes and animations. It is composed of four parts: reference library, case base manager, treatment adviser, and process builder. The system contains the cases of industrial and municipal real-life applications. It involves also several methods for automated construction of the treatment sequence for a given wastewater. The dataset includes 3D images and virtual tours to working process of a number of wastewater treatment technologies.

1. Introduction

The design of efficient water treatment systems is a complicated task which requires significant engineering experience as well as deep theoretical knowledge of the designers. 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 components 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. Therefore, an information reference system accumulating knowledge in the field of the wastewater treatment and water reuse in an easily accessible way would be of great interest to the engineers.

While approaches towards effective waste management, such as waste elimination at source, renewable energy, life cycle assessment and cleaner production technology have altered radically university curricula, traditional pollution control and technologies for clean-up processes remain an integral part of engineering education and have a lot to offer in environmental preservation and economic development (Brennecke & Stadtherr, 2002; Gutierrez-Martin & Huttenhain, 2003).

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. Computer science has created new tools for education, visualization and practical experience, in a rapid and cost-effective way, where the learners have fast and easy access to information and is

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allowed to experiment in design by testing several engineering scenarios (Paraskeva et al., 2007).

The objective of the presented work is the creation of effective training and reference computer system focusing on wastewater treatment and water reuse. The system contains the cases of industrial and municipal real-life applications. It can be used for training in selection of technologies for wastewater treatment including reclamation & reuse, without investment in expensive pilot plant infrastructure.

2. Features and functions of the training system

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

In more details the training system dealing with wastewater treatment should be able to offer to the learners the following:

- Theoretical knowledge of available technologies for wastewater treatment and reclamation.
- Practical understanding of the mechanisms involved in unit processes.
- The ability of designing a simple unit operation based on practical information.
- The possibility of accessing real industrial data on current practices and results.
- The ability to check simple problem-solving scenarios.
- The information to problem-solution practices.
- Applied techniques in wastewater minimization in regional industries.

This educational system combines the elements of traditional engineering education and modern computer-based virtual tools including theoretical information, virtual demonstration of technologies, spreadsheet models, a small database of case studies in select municipal and industrial sector and a basic case base reasoning system allowing the user to access the most suitable treatment sequence or create own one.

The primary target group for the training is students and academics. The system is by no means a substitute for a proper textbook and, in any case, despite containing a lot of theoretical material, must be supplemented by appropriate reading material and coursework.

3. Structure and components of the systems

The educational system is a package of computer applications supplemented by data files, text notes and animations. The system structure contains four modules (fig. 1):

1. Reference Library (RL) a structured e-book with theoretical knowledge on wastewater unit operation as well as training examples;
2. Case study Manager (CM), with case studies from real life applications;
3. Process Builder (PB) serves to construct a full treatment sequence from basic unit operations presented as blocks;
4. Treatment Adviser (TA) assists in problem-solving exercises;

The package can be divided into a theoretical part (RL, CM) and a practical part (PB, TA and models included in the RL). The components support the complete training activity from presentation to problem solving and design

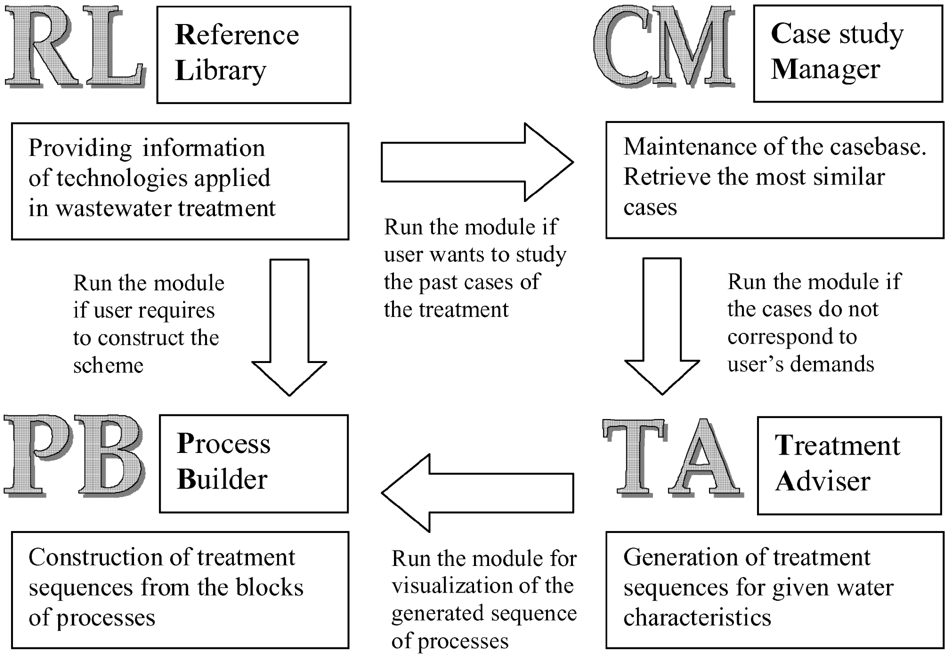

Figure 1. The active structure of educational system

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3.1 Reference Library

The purpose of the reference library is to provide the user with comprehensive overview of processes and operations used for water treatment. The general description of the water treatment technology is supplemented by the theoretical background with examples and a model.

The particular treatment processes are usually classified as physical operations, chemical and biological processes. Reference Library supports several classifications of the unit operations and processes. They are grouped according to the level of the provided treatment (preliminary, primary, secondary, and advanced treatment), type of unit operations (physical, chemical, biological) and in the alphabetic order.

The module provides the user with a comprehensive overview of 21 technologies used for wastewater treatment. Each item consists of the following sections:

- the theoretical background section; which is based on textbooks and published papers, and provides theoretical information about the principle of each technology as well as an analysis of the elements of each unit operation;
- the design parameters section provides practical information about the range of parameters used in the design of the technologies and in sizing the various tanks/reactors, usually in the form of comprehensive tables;

- the example section, which is a worked-out example in basic design and sizing each wastewater treatment unit operation. The examples were taken from working wastewater treatment plants, from real design studies, from textbooks. The user combines the information from the theoretical part such as mass balances, for example, and the practical information of the design parameters section in order to complete the example;
- the model, is a design model implemented in Microsoft Excel workbook, that solves the example from the previous section in computer form, one for each technology;
- the view section, where the user can find a schematic representation of each technology, view 3D image(s) of each process and also view a full animation with explanatory text showing and describing each process. In most cases 3D images were rendered from digital pictures and engineering drawings, from operating wastewater treatment plants. In animations, the user is taken in a virtual step-by-step walk through each process;
- the references section, where the user can find the textbooks used and material for further reading

The module is supplemented with list of terms used in the environmental engineering.

3.2 Case study Manager

The case study manager accumulates the specific design experience contained in real life situations, and tries to reuse it when solving new user's problems. The manager performs the retrieval of the most similar cases to the current problem from the case base containing the past situations of water treatment. The case base of the CM includes more than 100 case studies obtained from municipal and industrial wastewater treatment plants from Asia and Europe. The industrial sectors include pulp and paper mills, alcohol distilleries, tanneries, rubber and latex processing, textile and garment manufacturing and metal-finishing units.

The representation of a case includes lists of influent and effluent wastewater characteristics, divided into four groups (physical parameters, organic and inorganic matters and microbiological characteristics), short description of the plant generating wastewater, average flowrate, the sequence of treatment technologies and additional comments. Also, where available from the industry the cost of treatment per unit volume is included.

The module can be used to help in solving user problems, either by the user composing a new case study or a problem or by entering influent wastewater characteristics, demanded flow and sector of industry. In solving a current problem, a similar past problem and its solution are retrieved using a set of rules for measuring similarity between actual problem and those stored in case base.

In order to define a similarity between cases containing both numeric and textual-symbolic information the general similarity concept is used (Avramenko & Kraslawski, 2006). The treatment sequences of similar cases are provided as promising solutions.

3.3 Treatment Adviser

Treatment adviser generates a simple sequence of treatment technologies for a given water characteristics. It analyses the influent water characteristics and supplemented information of other factors (economical, technical or ecological) to select suitable technology of treatment.

There are two techniques to construct a sequence of treatment: based on set theory, analyzing the classes of contaminants in the wastewater, and based on decision trees, where the suitable technology selected according to logic gained from experts.
The first algorithm of selection is based on the search for deviations in wastewater parameters from those of clean environment (Avramenko, 2003). The goal is to eliminate the deviation, simply, to clean the wastewater. The deviations are determined by specific set of wastewater characteristics. For example, the phenol concentration in water above 50 mg/l and up to 500 mg/l defines the harmful factor "Middle concentrated phenol". Each deviation can be treated by a number of wastewater treatment technologies that are capable to eliminate the deviation in wastewater. The stream may contain a number of such deviations 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 applicability of the set of technologies is evaluated based on data from the past applications of these technologies.
Another algorithm is the selection of the proper wastewater treatment method based on previously constructed rules represented as decision tree. A decision tree can be defined as a map of the reasoning process (Negnevitsky, 2002). The tree is a graph or model of decisions and their possible consequences, including chance event outcomes, resource costs, and utility. The results of outcomes are retrieved from expert opinion and experience. By answering the question in the nodes of the tree the space of possible outcome reduces and finally a realization of treatment method is found in the end of the branch of the tree. The process of selection of treatment method from decision tree can be understand from the fig.2, where part of decision tree for selection of aerobic treatment type is presented. Each treatment level is considered consequently, and after successful passing all decision trees the final treatment sequence is constructed.

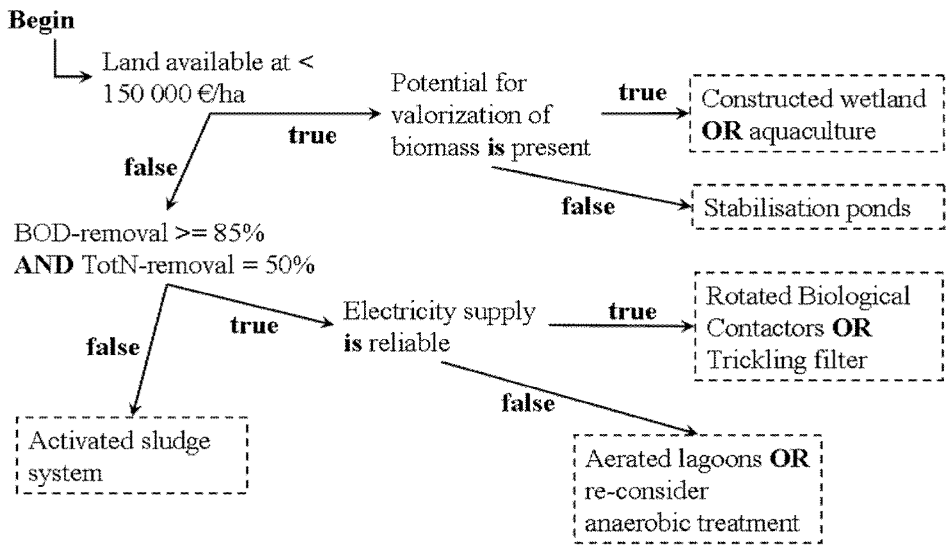

Figure 2. Decision tree for selection of type of aerobic treatment

3.4 Process Builder

Process builder serves to create a treatment system flow diagram from the unified blocks. Each of the blocks represents a type of the treatment processes or specific part of the process. Blocks can be linked according to internal restrictions, rules and locations of connection points. The module is based on a valid sequence matrix represents permission or the refusal of the sequence which is based on technical feasibility only and not on other parameters such as land availability, cost, energy consumption.

The aim of the module is that the user, after becoming familiar with the concept of the methods and with the practices used in the industry, creates one's own wastewater treatment sequence. The module is also used to visualize the result proposed by Treatment adviser.

4. Conclusions

The presented educational system 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 and students looking for the support to understand the wastewater treatment problems. One of the main functions of the educational system is to narrow the gap between the classroom teaching and real-life applications of wastewater treatment technologies.

The system provides an opportunity for the users to learn basing on the experience in wastewater treatment and approaches to water conservation in several countries in Asia and Europe. They also can have an overview of the theory & practice of wastewater treatment technologies applicable to municipal and various industrial sectors in Asia & Europe. One of the main advantages of the educational system is the visualization of operations involved in the wastewater treatment.

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