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Case-based Design of Soche (Blantyre, Malawi) Wastewater Treatment Plant

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This paper evaluates the applicability of case-based reasoning principles for the design of wastewater treatment facility in Blantyre, Malawi. The objective of the research was a comparison of the existing wastewater facility with the plant identified by the CBR system and suggestion of the eventual changes for the improvement.

1. Introduction

Rising population, rapid urbanization, growing industrialization and the expanding agro industry, combined with pollution from untreated sewage and industrial effluents have severely stressed both water quality and its availability in many countries. Therefore an issue of primordial importance is ability to design wastewater treatment plants able to deal with the existing challenges. In Sub-Saharan Africa, the lack of highly qualified wastewater treatment specialists makes these tasks even more difficult. The possibility of the re-use of design experience would create an opportunity for the efficient use of the existing human resources in construction of the wastewater treatment plants. The potentially applicable approach for re-use of design experience is case-based reasoning (CBR) The objective of the presented research is testing usefulness of CBR for the revamp of the existing wastewater treatment plant. The applicability of CBR has been assessed for the case of the wastewater facility existing in Blantyre, Malawi.

2. Data collection

The study was conducted at the treatment facility located at the south-western end of Blantyre, Malawi. This works serves a physical catchment area of some 24 km^2 comprising the south-west residential area of the city, 30% of the influent to the works is from the industrial areas. The average dry weather flow rate for the plant is 5,573 m^3/d. The works is a principal tanker reception centre for latrine and septic tank emptyings. On the average, about six tankers are received per day, totaling approximately 36 m^3/d. To monitor the facility operation, data was collected through site visits and a desk study which was based on the work by Kuyeli (2007). In (Kuyeli, 2007) sampling was done in the months of October to November, 2005 for the dry

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season. BOD_5 was determined by the Winkler method of oxygen measurement in the samples before and after incubating for five days at 20 ^{0}C, whereas TSS were determined by filtering the samples through pre-weighed glass fibre filters as described in APHA (1985). Table 1 shows data for influent and effluent BOD_5 and TSS levels in Blantyre plant.

Table 1 Influent / effluent BOD_5 and TSS for Blantyre plant for the dry season in mg/L

Parameter	**BOD**	**TSS**
Influent	490±9.8	157±2.32
Effluent	24.82±0.6	101.65±5.64
Reduction Efficiency (%)	*95*	*35*
Malawi Standard	20	30
W.H.O. Standard	20	30

2. Method of similarity analysis

Case-based design (CBD) is the commonly used mechanism of approximate reasoning in decision support systems. It offers a powerful environment for generalization of the accumulated experience represented as the collection of cases. The cases constitute the essence of the existing domain knowledge. When encountering a new situation, already collected cases are invoked and eventually modified to create a particular design alternative. The case-base should be organised into a manageable structure that supports the efficient search and retrieval methods. This is accomplished in the ED-WAVE tool (Avramenko and Kraslawski, 2008; Althoff et al.1995), (Figure 2). The system consists of four modules: Reference Library, Process Builder, Case Study Manager, and Treatment Adviser (Figure 1). The ED-WAVE tool was used for the conceptual design of the wastewater treatment works in Blantyre.

2.1 Reference Library

The purpose of the Reference Library is to provide the user with a comprehensive overview of processes and operations used for wastewater treatment. The general description of the wastewater treatment technology is supplemented by the theoretical models illustrated with the examples. The treatment processes are 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), and type of unit operations (physical, chemical, biological). 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 sizing the various tanks/reactors, usually in the form of comprehensive tables;
- the example section, presenting the cases taken from the existing wastewater treatment plants, The user combines the information from the theoretical part such as mass balances, and the practical information of the design parameters section in order to complete the example;
- the model implemented in Microsoft excel workbook
- the view section, with a schematic representation of each technology, view 3D image(s) of each process and also view a full animation with exemplary text showing and describing each process
- the reference section, with the textbooks and material for further reading.

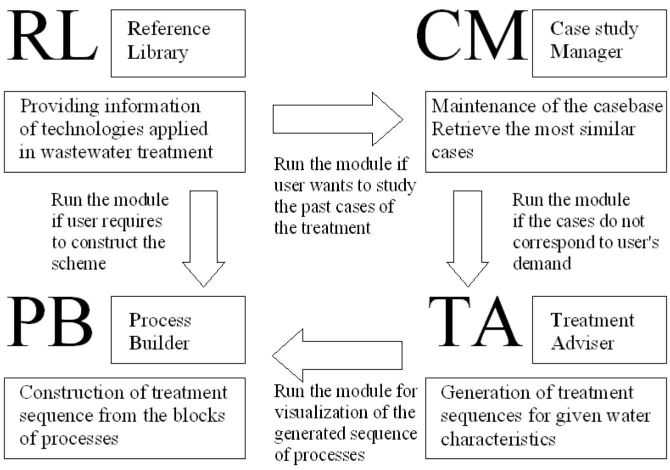


Figure 1: Structure of the ED-WAVE tool

2.2 Case Study Manager

The Case Study Manager accumulates the specific design experience contained in cases 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 composed of the past situations of wastewater treatment. The case base of the case study manager includes more than 100 case studies obtained from municipal and industrial wastewater treatment plants. The industrial sectors include pulp & paper mills, alcohol distilleries, tanneries, rubber and latex processing, textile and garment manufacturing, and metal finishing units. The representation of the case includes lists of influent and effluent wastewater characteristics, divided into four groups (physical parameters, organic and inorganic parameters, and microbiological characteristics), short description of the plant generating the wastewater, average flow rate, the sequence of treatment technologies and additional comments and for some cases the cost of treatment per unit volume. In order to define a similarity between cases containing both numeric and textual-symbolic information, the general similarity concept is used (Avramenko and

Kraslawski, 2008; Avramenko, 2005). The treatment sequences of similar cases are identified as promising solutions.

2.3 Treatment Adviser

Treatment Adviser generates a sequence of treatment technologies for a given water characteristics. It analyses the influent water characteristics and information on economical, technical or ecological factors to be used for the selection of suitable treatment technology; alternatively the user can use the Process Builder to construct a valid treatment sequence (Balakrishnan, 2005). It is uses the selection algorithm based on the previously developed rules represented as a decision tree. The tree is a graph or model of decisions and their possible consequences, including chance of the event outcomes, the resource costs, and utility. The selection process of treatment method from a decision tree is illustrated in Figure 2 . There is presented a fragment of decision tree for selection of an aerobic treatment. Each treatment level is analyzed, and after successfully passing all decision trees, the final treatment sequence is considered.

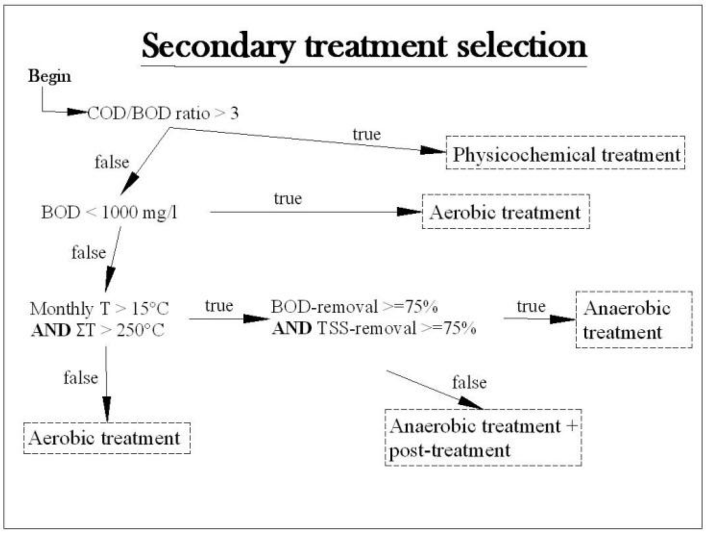


Figure 2: Decision tree for selection of an aerobic treatment type

2.4 Process Builder

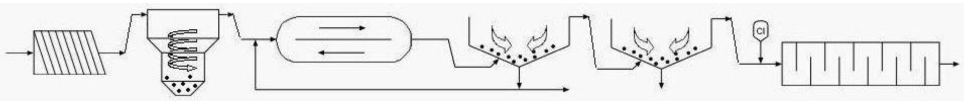
It is used to create a flow diagram of treatment system. This system is composed of the unified blocks. Each block represents a type of treatment process or specific part of the process. The blocks can be linked according to internal restrictions, rules and locations of connection points. The module is based on a sequence matrix and is based on technical feasibility exclusively and not other parameters such as land availability, cost, or energy consumption.. The module is used to visualize the result proposed by the Treatment Adviser or to illustrate the actual sequencing of treatment units at a particular plant.

3. Results

According to the Case Study Manager in the ED-WAVE tool, a similar case to the dry season conditions is case 6 presented in Table 2. The treatment sequence for this plant and the comparative sequencing of the treatment units at the Blantyre plant, dry season, and the actual sequencing of treatment units are given in Table 2. Figures 3, 4, and 5 illustrate this sequencing according to the Process Builder in the ED-WAVE tool.

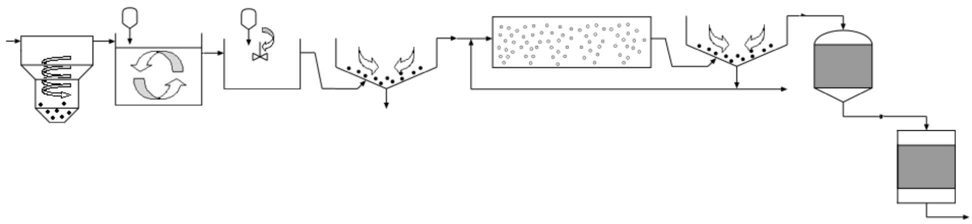
Table 2 Comparative sequencing of treatment units

Plant		**Suggested sequencing**	**Actual sequencing**
Step	**Case 6**		
No.			
1	Screening	Grit chamber	Screening
2	Grit chamber	Neutralisation	Grit chamber
3	Oxidation ditch	Chemical precipitation	Primary sed.
4	Sedimentation	Activated sludge process	Trickling filters
5	Chlorination	Activated carbon adsorp.	Humus tanks
6	-	Ion exchange	Sand filters



Screening ---------Grit Removal-------------Oxidation Ditch-----------Sedimentation---- -----------Chlorination-----Effluent

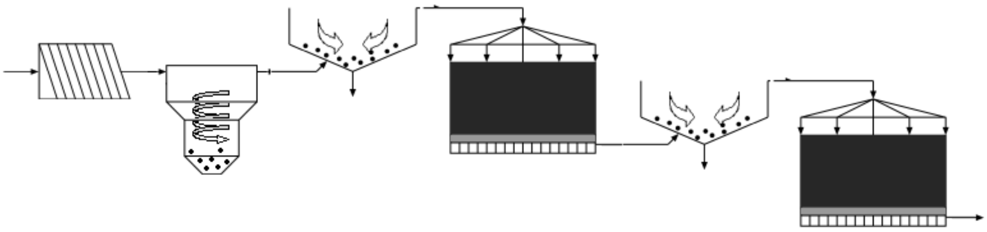
Figure 3: Sequencing of treatment units - Case 6



Grit Removal --------Neutralisation----------Chemical Precipitation------------- Activated Sludge Process---------Activated-----Ion Exchange

Carbon Dosing

Figure 4: Suggested sequencing of treatment units for dry season conditions at Soche WWT



----- Screening-------- Grit Removal---Primary Sedimentation----Trickling Filters-----
---Humus Tanks------Sand Filters (disused)--Effluent

Figure 5: Actual sequencing of treatment units for Soche plant

4. Discussion

A similarity between case 6 and the actual set up at Blantyre works is the provision for screening. Screening is necessary in developing countries because of the nature and quantity of solids present in the sewage. BOD_5 and TSS effluent levels at Blantyre were 24.82 mg/L and 101.65 mg/L, respectively, in the dry season. This represented a BOD_5 and TSS removal efficiency of 95 % and 35 %, respectively in the dry season. The study further established that BOD_5 and TSS levels in the effluent are higher at Blantyre than the set standards. A critical analysis of the results suggests that there are certain treatment units to be added to Blantyre plant. These include the grit removal process, for removal of inorganic grit. The ED-WAVE suggested the mechanised grit chambers. Finally the inclusion of an aerobic biological treatment process is necessary to ensure that a substantial quantity of organic matter in liquid state is oxidized prior to discharge into public water. Blantyre plant applies trickling filters for this process while case 6 uses oxidation ditches. An inclusion of the chlorination stage at case 6, the ion exchange stage and the filtration process in the actual sequencing for this plant relates to the need for a tertiary treatment stage.

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