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ED-WAVE tool design approach: case of Limbe wastewater treatment works, Blantyre, Malawi

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ABSTRACT

The ED-WAVE tool is a PC based package for imparting training on wastewater treatment technologies. The system consists of four modules viz. Reference Library, Process Builder, Case Study Manager, and Treatment Adviser. The principles of case-based design (CBD) and case-based reasoning (CBR) as applied in the ED-WAVE tool are utilised in this paper to evaluate the design approach of Limbe wastewater treatment works (Limbe WWTW) in Malawi. The plant has an average dry weather flow rate of 1,800 m^3/d. The study established that a similar case to both the dry season and wet season conditions of Soche wastewater treatment works has similarities to Municipal Case 1 in Sri Lanka, with a flow rate of 1,700 m^3/d. The study further established that that there are certain unit treatment processes that are important in wastewater treatment. These include a primary sedimentation process, achieved through the imhoff tank at the plant in Sri Lanka, chemical precipitation followed by sedimentation as suggested by the dry season and wet season unit treatment processes, and the receiving pond in the actual set up at Limbe. Municipal Case 1 in Sri Lanka utilises trickling filters for aerobic biological treatment while the Limbe plant accomplishes this process through the facultative ponds. The suggested sequencing of dry and wet weather conditions by the Treatment Adviser provides for activated sludge for aerobic biological treatment. Screening is incorporated at the Limbe plant. This process is not there at Municipal Case 1 in Sri Lanka. Screening is necessary in developing countries because of the nature and quantity of solids present in sewage, which include still born babies, maize cobs and pieces of cloth used for anal cleaning, and domestic garbage. Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), and Total Dissolved Solids (TSS) removal efficiency in the dry season was 93%, 40% and 93%, respectively. The study further established that the BOD_5, COD and TSS removal efficiency in the wet season was 92%, 5% and 20%, respectively. BOD_5, COD and TSS removal efficiency at the plant in Sri Lanka was 83%, 76% and 77%, respectively. The close correlation in the treatment processes at Municipal Case 1 in Sri Lanka, the suggested dry and wet season unit treatment processes according to the Treatment Adviser, and the actual set up at Limbe WWTW confirms the practical use of CBD and CBR principles in the ED-WAVE tool in the design of wastewater treatment systems.

Keywords: Aerobic biological treatment; Case-based design; Grit removal; Humus tank; Imhoff tank; Unit treatment processes

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1. Introduction

Wastewater needs to be dully treated in order to minimize its negative effects on people, animals, birds, and aquatic biota. Polluted water is unsuitable for drinking, recreation, agriculture, and industry. It diminishes the aesthetic quality of surface water sources [14]. In order to reduce the undesirable effects of wastewater, it is necessary to treat it to meet the consent requirements of effluent quality set by the environmental regulatory agency [6].

Wastewater treatment is the engineering process that employs physical, biological, and chemical processes to reduce the concentration of pollutants found in wastewater to a harmless or near-harmless level in the effluent [6]. Wastewater treatment plants are large non-linear systems subject to large perturbations in wastewater flow rate, load and composition. Nevertheless these plants have to be operated continuously meeting stricter and stricter regulations [13].

This paper evaluates a design approach of Limbe wastewater treatment works (Limbe WWTW) using the principles of case-based design (CBD) and case-based reasoning (CBR) as incorporated in the ED-WAVE tool [1–3].

2. Methodology

2.1. Study area

The study focused on Limbe WWTW whose catchment is situated on the eastern edge of the Blantyre urban area and serves parts of the wards of Chichiri South, Limbe Central and Limbe West. Blantyre is Malawi's commercial capital, with a population of 661,256 [19]. The city of Blantyre lies within the Shire Highlands, with a topography ranging from 800 m to 1600 m, in the southern part of Malawi. Malawi lies between latitudes 9 and 17 degrees South and between longitudes 33 and 36 degrees East [18] Limbe WWTW catchment contains a large area of principally commercial properties, the main railway workshops of Malawi and numerous industrial premises. The treatment facilities consist of a waste stabilisation pond system, which was originally established in the 1970's and comprised an inlet works with manually raked screens, grit channels and a flow-measuring flume, followed by a series of four stabilisation ponds. The works was extended by the construction of a further twelve ponds which were commissioned in 1985. The waste stabilisation pond treatment system thus currently comprises the original inlet works followed by four parallel four pond series (Fig. 1) [9].

2.2. Data collection and analysis

Data was collected through a desk study, which was based on the work by Kuyeli [14]. Sampling was done between the months of October to November, 2005 for the dry season, and February, 2006 for the wet season using the grap sampling method. Samples were collected using one-liter plastic bottles that had been cleaned by soaking in 10% nitric acid, and rinsed several times with distilled water. Three one-liter samples were collected at each point. Biochemical Oxygen Demand (BOD_5) was determined by the Winkler method of oxygen measurement in the samples before and after incubating for five days at 20 °C, whereas Total Dissolved Solids (TSS) were determined by filtering the samples through pre-weighed glass fibre filters. Chemical Oxygen Demand (COD) was determined by adding 10 ml aliquot of standard potassium dichromate (0.02 M) containing mercuric sulphate and 30 ml of sulphuric acid containing silver sulphate to about 20 ml of the homogenized sample in the reflux condenser. The mixture heated for 2 h in the range of 148 °C and 150 °C and then cooled to room temperature. The condenser was washed by distilled water and the final mixture was used to make 100 ml solution, which was titrated against 0.12 M ammonium iron (II) sulphate (FAS) using ferroin indicator.

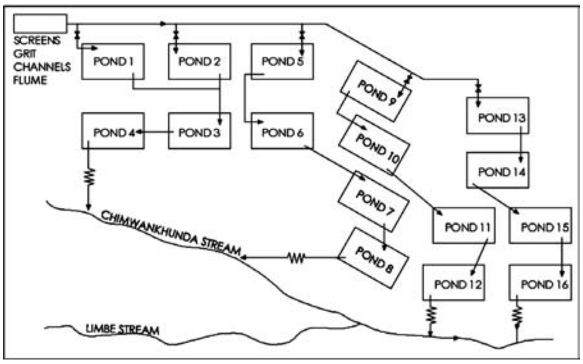

Fig. 1. Waste stabilisation pond system at Limbe WWTW: *Source:* Carl Bro International, 1995.

COD levels were calculated using the following equation:

$$\text{COD} = \frac{8000(b - s)n}{Sample(ml)}$$

where b is the volume of FAS used in the blank sample, s is the volume of FAS in the original sample, and n is the normality of FAS [14].

A mean concentration was calculated along with a standard deviation on the results obtained for three samples collected from each point.

2.3. The ED-WAVE tool

The ED-WAVE tool was used for the conceptual design of Limbe wastewater treatment plant in the city

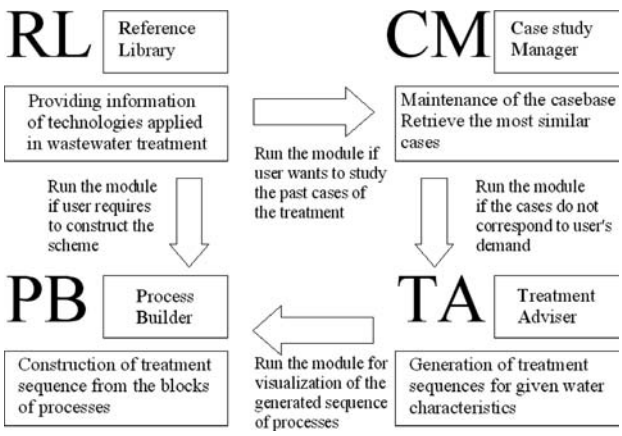

Fig. 2. Schematic diagram of the ED-WAVE software structure; *Source:* Ref. [25].

of Blantyre. The tool consists of virtual industrial and municipal environments created using an IT based tool using real-life applications.

The ED-WAVE tool is a shareware PC based package for imparting training on wastewater treatment technologies. The system consists of four modules viz. Reference Library (RL), Process Builder (PB), Case Study Manager (CM), and Treatment Adviser (TA) (Fig. 2) [5,25].

2.3.1. Reference library

The purpose of the RL 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 background with examples and a model.

The particle treatment processes are usually classified as physical operations, chemical and biological processes. RL 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, and 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, which is a worked out example in basic design and sizing of each wastewater treatment unit operation. The examples were taken from operational wastewater treatment plants, from real design studies, from textbooks. 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 is a design model implemented in Microsoft excel workbook, that resolves the example from the previous section in computer form, one for each technology;
- the view section, where a user can find 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. 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 reference section, where the user can find the textbooks used and material for further reading.

The model is supplemented with a list of terms used in environmental engineering.

2.3.2. Case study manager

The CM 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 wastewater 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 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. Also, where available from the particular 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 the case base.

In order to define a similarity between cases containing both numeric and textual-symbolic information, the general similarity concept is used [3,4]. The treatment sequences of similar cases are provided as promising solutions.

2.3.3. Treatment adviser

TA 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 a suitable treatment technology; alternatively the user can use the PB to construct a valid treatment sequence [5]. This is based on the algorithm of selection of the proper wastewater treatment method based on previously constructed rules represented as a decision tree. A decision tree (or tree diagram) is a map of the reasoning process [24]. The tree is a graph or model of decisions and their possible consequences, including chance event outcomes, resource costs, and utility. It is a decision support tool that uses a tree-like graph or model of decisions and their possible consequences (http://www.mindtools.com/dectree.html). It provides a highly effective structure within which to explore options, and investigate the possible outcomes of changing those options. The results of outcomes are retrieved from expert opinion and experience.

2.3.4. Process builder

The PB is the last module in the ED-WAVE tool. It serves to create a treatment system flow diagram from the unified blocks. Each of the blocks represents a type of treatment process 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 and is based on technical feasibility only and not other parameters such as land availability, cost, or 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 the TA or to illustrate the actual sequencing of treatment units at a particular plant as illustrated if Figs. 3 and 4.

The tool is based on the principles of CBD and CBR as applied in Process Systems Engineering [1,3].

2.4. Case-based design

CBD is one of the commonly used mechanisms of approximate reasoning in intelligent systems and decision support systems. These mechanisms offer a powerful

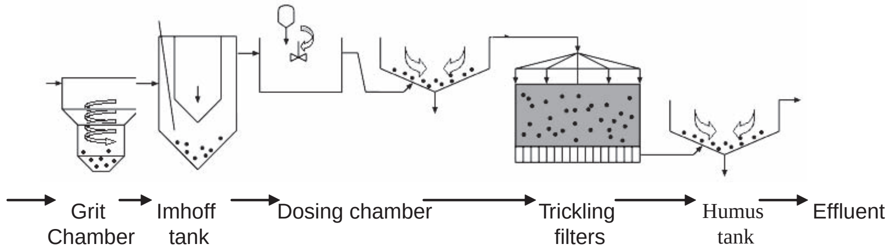

Fig. 3. Sequencing of treatment units at Municipal Case 1, Sri Lanka, according to the PB.

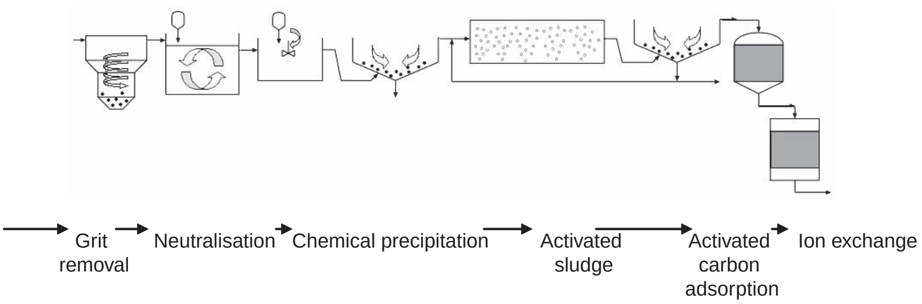

Fig. 4. Suggested sequencing of treatment units for dry and wet season conditions at Limbe WWTW.

and general environment in which is generalized a basis of already accumulated experience being represented in the form of a finite and relatively small collection of cases. Those cases constitute the essence of the existing domain knowledge. When encountering a new situation, already collected decision scenarios (cases) are invoked and eventually modified to arrive at a particular design alternative. Case storage is an important aspect in designing efficient CBD systems in that it should reflect the conceptual view of what is represented in the case and take into account the indices that characterise the case. 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 (Fig. 2) [3].

2.5. Case-based reasoning

Case-based problem solving is based on the premise that a design problem solver makes use of experiences (cases) in solving new problems instead of solving every new problem from scratch [15]. Lanson argues that "innovation arises from incremental modification of existing ideas rather than entirely new approaches" [16]. Coyne classify the case based approach into three activities: creation, modification, and adaptation [12]. Creation is concerned with incorporating requirements to create a new prototype. Modification is concerned with developing a working design from a particular category of cases. Adaptation is concerned with extending the boundaries of the class of the cases.

CBR solves new problems by adapting previously successful solutions to similar problems. A CBR approach can handle incomplete data: it is robust with respect to unknown values because it does not generalize the data. Instead, the approach supports decision making relying on particular experience [3].

3. Results

3.1. Operational data for Limbe WWTW

Tables 1 below shows the influent and effluent characteristics of the wastewater at Limbe WWTW during the dry season and wet season, respectively, with corresponding Malawi effluent standards and WHO guidelines [17,26]. The Table also shows the influent and effluent characteristics of Municipal Case 1 in Sri Lanka.

The BOD_5 and TSS removal efficiency in the dry season was 93% for both parameters. The COD removal efficiency was 40%. BOD_5, COD and TSS removal efficiency in the wet season was 92%, 5% and 20%, respectively.

The mean effluent BOD_5 and COD levels for both the wet and dry season are above the Malawi standard. The effluent TSS level in the dry season is below the Malawi standard while the level in the wet season is above the Malawi standard.

3.2. Application of CBD and case-based reasoning principles in the design of Limbe WWTW

According to the CM in the ED-WAVE tool, a similar case to both the dry season and wet season conditions of Limbe wastewater treatment works has similarities to Municipal Case1 in Sri Lanka, with a flow rate of 1,700 m^3/day. The treatment sequence for this plant and the comparative sequencing of the treatment units at the Limbe plant, dry and wet season, and the actual sequencing of treatment units at Limbe treatment works

Table 1
Limbe WWTW influent and effluent physicochemical characteristics for the dry season and wet season in mg/l with comparative data for Municipal Case 6 in Sri Lanka

Parameter	BOD	COD	TSS
Dry season			
Influent	740 ± 10.1	740 ± 10.1	220 ± 0.0
Effluent	50.5 ± 1.0	50.5 ± 1.0	16.04 ± 0.19
Reduction Efficiency (%)	93	40	93
Wet season			
Influent	810.5 ± 41.72	821.32 ± 10.06	268.45 ± 3.56
Effluent	63.0 ± 4.24	778.56 ± 19.20	214.0 ± 2.96
Reduction Efficiency (%)	92	5	20
Municipal Case 1 in Sri Lanka			
Influent	152	198	110
Effluent	26	47	25
Reduction Efficiency (%)	83	76	77
Malawi Standard	20	60	30
WHO Guidelines	20	60	30

Table 2
Comparative sequencing of treatment units

Plant/Step No.	Municipal Case 1, Sri Lanka	Suggested sequencing of dry season conditions by TA	Suggested sequencing of wet season conditions by TA	Actual sequencing of Limbe plant
1	Grit chamber	Grit removal	Grit removal	Screening
2	Imhoff tank	Neutralisation	Neutralisation	Grit Chambers
3	Dosing chamber	Chemical precipitation	Chemical precipitation	Receiving pond
4	Trickling filters	Activated sludge	Activated sludge	Facultative pond
5	Humus tank	Activated carbon	Activated carbon	Maturation ponds
6		Ion exchange	Ion exchange	

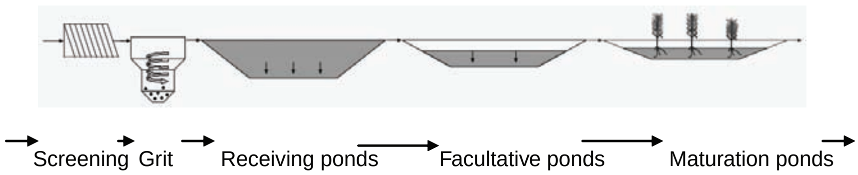

Fig. 5. Actual sequencing of treatment units for Limbe WWTW.

are illustrated in Table 2. Figs. 2–4 further illustrate this sequencing according to the PB in the ED-WAVE tool. Fig. 5 illustrates actual sequencing of treatment units for Limbe WWTW".

4. Discussion and conclusion

Through this study, CBD principles in the ED-WAVE tool gave Municipal Case 1 in Sri Lanka as a wastewater treatment plant similar to Limbe WWTW. The plant in Sri Lanka has five unit treatment processes, namely: grit chamber, imhoff tank, dosing chamber, trickling filters and a humus tank. The dry season and wet season set up for Limbe both have a grit chamber, neutalisation process, chemical precipitation, activated sludge, activated carbon adsorption, and an ion exchange process. The actual sequencing at Limbe plant essentially has three processes: screening, grit chambers, and a four-stabilisation pond system comprising of receiving ponds, facultative ponds, primary maturation ponds and secondary maturation ponds (Fig. 1). The similarities between Municipal Case 1 in Sri Lanka and the actual set up at Limbe include the provision of grit chambers for the removal of inorganic grit, a primary sedimentation process for anaerobic treatment: an imhoff tank in the case of Municipal Case 1 in Sri Lanka, and receiving ponds in the case of Limbe plant. Municipal Case 1 in Sri Lanka utilises trickling filters for aerobic biological treatment while the Limbe plant accomplishes this process through the facultative ponds. A screening process is incorporated in the actual set up at Limbe. This process is not there at Municipal Case1 in Sri Lanka.

Screening is necessary in developing countries because of the nature and quantity of solids present in the sewage, which include still born babies, maize cobs and pieces of cloth used for anal cleaning, and domestic garbage [8,10,11,14,20].

The primary and secondary maturation pond system provides for good polishing up of the wastewater before it is discharged into the receiving river course. Further work is required to determine the impact of the effluent upon the aquatic flora and fauna, the pathogen content of the effluent and risk to public health of users who abstract water from the receiving watercourse for domestic and irrigation purposes.

The study established that the $BOD_{5,}$ COD and TSS removal efficiency in the dry season was 93%, 40% and 93%, respectively. The study further established that the $BOD_{5,}$ COD and TSS removal efficiency in the wet season was 92%, 5% and 20%, respectively. $BOD_{5,}$ COD and TSS removal efficiency at the plant in Sri Lanka was 83%, 76% and 77%, respectively. A close look at the unit treatment processes at the plant in Sri Lanka, the suggested dry season and wet season unit treatment processes, and the actual set up at Limbe plant suggests that there are certain unit treatment processes that are important in wastewater treatment. These include a primary sedimentation process, achieved through the imhoff tank at the plant in Sri Lanka, chemical precipitation followed by sedimentation as suggested by the dry season and wet season unit treatment processes, and the receiving pond in the actual set up at Limbe.

In municipal wastewater treatment, sedimentation is the main process in primary treatment, where it is responsible for removing 50–70% of the suspended solids (containing 25–40% of BOD_5) from the wastewater [7,22].

Another unit treatment process common to all four set ups in Table 2 is an aerobic biological treatment process. Municipal Case 1 in Sri Lanka utilises trickling filters, the dry and wet season set up according to the TA utilises the activated sludge process, and the actual set up at Limbe utilises facultative ponds. Aerobic biological treatment ensures that a substantial quantity of organic matter in liquid state is oxidized prior to the effluent being discharged into public water courses where it would otherwise exert an oxygen demand [7]. Facultative ponds, the technology utilised at Limbe WWTW, are cheap to construct. Waste stabilisation ponds are large shallow basins enclosed by earthen embankments in which wastewater is biologically treated by natural processes involving pond algae and bacteria [20,21].

The inclusion of activated carbon dosing and ion exchange in the suggested dry and wet season probably relates to the need for a tertiary treatment stage for these works. This tertiary treatment would be necessary for polishing up the effluent [7,22]. This tertiary treatment is accomplished by the primary and secondary maturation ponds at Limbe WWTW.

The close correlation in the treatment processes at Municipal Case 1 in Sri Lanka, the suggested dry and wet season unit treatment processes according to the Treatment Adviser, and the actual set up at Limbe WWTW confirms the practical use of CBD and case-based reasoning principles in the ED-WAVE tool in the design of wastewater treatment systems. After encountering a new situation, already collected decision scenarios (cases) are invoked and modified inorder to arrive at a particular design alternative.

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References

[1] K. Althoff, E. Auriol, R. Barietta and M. Manago, A Review of Industrial Case-Based Reasoning Tools. A1 Perspectives, Oxford, 1995.
[2] Y. Avramenko, Case-Based Design Method for Chemical Product and Processes Development. PhD Thesis, Department of Chemical Technology, Lappeenranta University of Technology, Finland, 2005.
[3] Y. Avramenko and A. Kraslawski, Case-Base Design. Springer: Berlin, 2008.
[4] Y. Avramenko, V. Chipofya and A. Kraslawski, Educational training system for design of efficient water treatment systems. (ICHeap09), Italy, 2009.
[5] M. Balakrishnan, V.S. Batra, P. Panagiota, E. Diamadopoulos, P. Paraskeva, A. Kraslawski, Y. Avramenko, D. Guiterrez, N. Ratnayake, W.B. Gunawarrdana, S. Siripathyi and T. Mung charoen, ED-WAVE Tool: Wastewater Treatment Technologies. Asia Link, EuropeAid, Geneva, 2005.
[6] C.G. Banda, Computational Fluid Dynamics Modeling of Baffle Waste Stabilisation Ponds. PhD Thesis, Civil Engineering, University of Leeds, UK, Leeds, 2007.
[7] D. Barnes, Water and Wastewater Engineering Systems. Pitman, London, 1981.
[8] S. Cairncross and R.G. Feachem, Environmental Health Engineering in the Tropics. Wiley, London, 1993.
[9] Carl Bro International. Sanitation Master Plan for the City of Blantyre: Existing Sanitation Situation Volume III. Government of Malawi, 1995.
[10] V. Chipofya, A. Kraslawski and Y. Avramenko, Design Approach of Blantyre Wastewater Treatment Plant, Malawi, Using the ED-WAVE Tool, Water, Sanitation and Hygiene: Sustainable Development and Multisectoral Approaches, 34th WEDC International Conference, 135-138, Addis Ababa, Ethiopia, 18-22 May, 2009.
[11] V. Chipofya, A. Kraslawski and Y. Avramenko, Comparison of wastewater treatment technologies in the ED-WAVE tool to technologies of similar cases in Malawi: case of Blantyre and Soche WWTW, Open Civil Engineering Journal, Bentham Publishing, (in press).
[12] R.D. Coyne, M.A. Roseman, A.D. Radford, M. Balachandran and J.S. Gero, Knowledge-based design systems, Reading, Addison-Wesley, USA, 1990.
[13] K.V. Gernaey, U. Jeppson, J.B. Vanrolleghern, Copp and J. Steyer, Benchmarking of Control Strategies for Wastewater Treatment Plants. IWA Publishing, ISBN 9781843391463, 2009.
[14] S.M. Kuyeli, Assessment of Industrial Effluents and their impact on Water Quality in Streams of Blantyre City, Malawi. MSc Thesis, Faculty of Science, University of Malawi, Zomba, 2007.
[15] J.L. Kolonder, Case-based reasoning. Morgan Kaifman, San Mateo, USA, 1993.
[16] J. Landson, Design Studies. 8(2) (1987), 76-81.
[17] Malawi Bureau of Standards – MBS (2005) Malawi Standards; Drinking Water Specification. Malawi Standards Board; MS 214:2005, ICS 13.030.40 (First revision).
[18] Malawi Government. Integrated Water Resources Management and Water Efficiency (IIWRM/WE) Plan. Malawi Water Partnership, Ministry of Water Irrigation and Water Development, Government of Malawi, Lilongwe, 2007.
[19] Malawi Government. Population and Housing Report. National Statistical Office, Government of Malawi, Zomba, 2009.
[20] D.D. Mara, Sewage Treatment in Hot Climates. ELBS/Wiley, London, 1976.
[21] D.D. Mara, Wastewater Treatment in Developing Countries. Earthscan Publications, London, England. ISBN 1844070190, 2004.
[22] Metcalf and Eddy, Wastewater Engineering Treatment, Disposal and Reuse. McGraw-Hill International, New York, 4th Edition, 2004.
[23] Mind Tools, Decision Tree Analysis, http://www.mindtools.com/decree.html, accessed 16.07.2009.
[24] M. Negnevitsky, Artificial Intelligence: A guide to intelligence systems. Pearson Education Limited, Addison-Wesley, Great Britain, 2002.
[25] P. Parakeva, E. Diamadopoulos, M. Balakrishnan, V.S. Batra, A. Kraslawski, Y. Avramenko, N. Ratnayake, B. Gunawarrdana, D. Gutierrez, O. Anson and T. Mungcharoen, ED-WAVE: an Educational software for training in wastewater technologies using virtual application sites. International Journal of Engineering Education, Tempus Publications, Great Britain, Vol. 23, No. 6, 1172–1181, 2007.
[26] World Health Organisation. Guidelines for drinking water quality. Recommendations. Vol. 2, 2nd Ed. World Health Organisation, Geneva, 1996.