34th WEDC International Conference, Addis Ababa, Ethiopia, 2009

WATER, SANITATION AND HYGIENE:
SUSTAINABLE DEVELOPMENT AND MULTISECTORAL APPROACHES

Design approach of Blantyre Wastewater Treatment Plant using the ED-WAVE Tool, Malawi

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REVIEWED PAPER 321

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 and case-based reasoning as applied in the ED-WAVE Tool are utilised in this paper in evaluating the design approach of Blantyre wastewater treatment plant in Malawi. The study established that a similar case to both the dry season and wet season conditions of Blantyre wastewater treatment works has similarities to Municipal Case 6 in Greece (2003), with a flow rate of 6,600m^3/day. Biochemical Oxygen Demand (BOD_5) and Total Suspended Solids (TSS) removal efficiency in the dry season was 87% and -11%, respectively, and 12% and 11%, respectively, in the wet season at the Blantyre plant. BOD_5 and TSS removal efficiencies at Municipal Case 6 in Greece was 95% and 95.5%, respectively. The study confirmed the practical use of the ED-WAVE Tool in the design of wastewater treatment systems. The study also confirmed the importance of screening, grit removal, aerobic biological treatment, and sedimentation in wastewater treatment processes.

Introduction

Wastewater needs to be duly 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 (Kuyeli, 2007). 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 (Banda, 2007).

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 (Banda, 2007).

Case-based design and Case-based reasoning

Case-based design and case-based reasoning are some of the commonly used mechanisms of approximate reasoning in intelligent systems and decision support systems. These mechanisms offer a powerful and [illegible]nment 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.

This paper evaluates a design approach of Blantyre wastewater treatment plant using the ED-WAVE Tool in which the principles of case-based design and case-based reasoning are embedded (Althoff, et.al., 1995; and Avramenko and Kraslawski, 2008).

Methodology

Data collection

Data was collected through a desktop study on the operational data maintained for Blantyre wastewater treatment plant, Malawi, and through personal communication with the Pollution Control Officer, Blantyre City Assembly. Separate data was collected for the dry season and the wet season (i.e. the two seasons prevalent in Malawi). For this one wastewater treatment plant, therefore, this gave a total of two cases for this study. The data was analysed using excel.

The ED-WAVE tool

The ED-WAVE tool was used for the conceptual design of Blantyre wastewater treatment works in the City 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).

The RL module gives a comprehensive overview of each technology through visuals of real life units accompanied by animations to explain the sequence of operation. This is supplemented by the theoretical description that, in turn, is illustrated by a worked out example and an excel spreadsheet model. The user can modify or select parameters in the spreadsheet to understand the effect on the unit performance. The CM consists of a collection of case studies obtained from municipal and industrial wastewater treatment plants from both 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.

For a user specified wastewater stream, the TA generates a treatment sequence; alternatively the user can use the PB to construct a valid treatment sequence (Balakrishnan, et.al. 2005). The tool is based on the principles of Case-Based Design and Case-Based Reasoning as applied in Process Systems Engineering (Althoff, et.al., 1995; Avramenko and Kraslawski, 2008).

Operational data for Blantyre Wastewater Treatment Plant

Table 1 shows the data for influent and effluent characteristics of the Blantyre wastewater treatment plant in the City of Blantyre, Malawi.

Table 1. Influent and effluent physicochemical characteristics of wastewater at the Blantyre wastewater plant, expressed in mg/l except for temperature and pH (Flow rate: 6,700 m^3/d)

Parameter/ Dry Season	Cl^-	DO	BOD	COD	T	pH	Alkalinity	TSS	EC	NO_3^-
Influent	34.8	0	440.0	1642.3	27	6.6	400	210	7	44.8
Effluent	33.4	1.2	58.0	691.03	27	7.3	610	233	9	153.0
Reduction Efficiency %	*4*	+	*87*	*58*		*-32*	*-53*	*-11*	*-29*	*-241*
Wet Season										
Influent	36.9	1.4	510	691.1	25.8	6.7	400	29.0	4.5	84.47
Effluent	36.2	2.6	450	503.01	26.6	7.0	370	25.9	4.1	32.37
Reduction Efficiency %	*2*	+	*12*	*27*	*-3*	*-5*	*8*	*11*	*9*	*62*

Key: Cl^- - Chloride; DO – Dissolved Oxygen; BOD – Biochemical Oxygen Demand; COD – Chemical Oxygen Demand; T – Temperature; TSS – Total Suspended Solids; EC – Electrical Conductivity; NO_3^- – Nitrate; + for DO means level increased; Source: Kuyeli, 2007

Design approach for the treatment plant using the ED-WAVE Tool

According to the Case Study Manager in the ED-WAVE tool, a similar case to both the dry season and wet season conditions of Blantyre wastewater treatment works is Municipal Case 6 in Greece (2003), with a flow rate of 6,600m^3/day. The treatment sequence for this plant and the comparative sequencing of the treatment units at the Blantyre plant, dry and wet season, and the actual sequencing of treatment units at Blantyre works are illustrated in Table 2 below.

Table 2. Comparative sequencing of treatment units

Plant/ Step No.	Municipal Case 6, Greece	Suggested sequencing of dry season conditions by Treatment Advisor	Suggested sequencing of wet season conditions by Treatment Advisor	Actual sequencing for Blantyre plant
1	Screening	Grit Chamber	Grit Chamber	Screening
2	Grit Chamber	Neutralisation	Neutralisation	Grit Channels
3	Oxidation Ditch	Chemical Precipitation/ Sedimentation	Chemical Precipitation/ Sedimentation	Primary Sedimentation
4	Sedimentation	Activated Sludge Process	Activated Sludge Process	Trickling Filters
5	Chlorination	Facultative Lagoon	Activated Carbon Adsorption	Humus Tanks
6	-	Activated Carbon Adsorption	Ion Exchange	Aeration Ponds

Discussion and conclusion

In this study, the Treatment Adviser in the ED-WAVE Tool gave Municipal Case 6 in Greece as a wastewater treatment plant similar to Blantyre wastewater treatment plant. The plant in Greece has five unit treatment processes. Both the dry and wet season set up for Blantyre works has six unit treatment processes. The actual sequencing for Blantyre works also has six unit treatment processes. One of the similarities between Municipal Case 6 in Greece and the actual set up at Blantyre works is the provision for screening.

The study established that the BOD5 and TSS removal efficiency in the dry season was 87% and -11%, respectively. The study further established that the BOD5 and TSS removal efficiency in the wet season was 12% and 11%, respectively. The reason for the rise in the effluent TSS level in the dry season needs to be investigated. A critical analysis of the unit treatment processes at the plant in Greece, the proposed dry and wet season unit treatment processes and the actual set up at the Blantyre plant suggests that there are certain unit treatment processes that are key in wastewater treatment. These include the grit removal process. However, the Blantyre plant uses constant velocity grit chambers, in which longitudinal flow velocity is controlled hydraulically. These are simple to operate and maintain because they do not require electrical/mechanical equipment. Two chambers are constructed in parallel. Grit is manually removed from one chamber whilst the other is still in use (Barnes, 1991). The ED-WAVE Tool mentions about mechanised grit chambers which are not ideal for Blantyre in terms of initial cost and the skills required for their operation and maintenance. The sedimentation process is also necessary for the removal of readily settleable matter from the wastewater. Through this process, a BOD5 reduction of 25-40%, and a TSS reduction of 50-70% is achieved (Barnes, 1981; Metcalf & Eddy, 2003). 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 the effluent being discharged into public water courses where it would otherwise exert an oxygen demand. The Blantyre plant uses trickling filters for this process while Municipal Case 6 in Greece uses oxidation ditches. Trickling filters are a preferred technology for Blantyre because their initial cost is lower, and they do not require skilled labour for their operation and maintenance.

The Municipal Case 6 in Greece, the dry and wet season plant set up from the ED-WAVE Tool, and the actual plant set up at Blantyre works all have the key unit treatment processes. However, the similarity

between Municipal Case 6 in Greece, and the actual set up of the Blantyre works confirms the practical use of the ED-WAVE Tool in the design of wastewater treatment systems.

Acknowledgements

The authors would like to thank the CIMO-NSS programme in Finland for the financial support which made it possible for this study to be carried out.

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Keywords

Aerobic biological treatment, oxygen demand, screening, unit treatment process, wastewater treatment

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