WASDA as a Decision Support System for Membrane Process: The Case of MBR and RO

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Abstract

This paper describes the capability of WASDA as a decision support system for membrane process, which is mainly used to treat industrial and domestic wastewater treatment. The objective of this study was to provide support system that narrowly served efficient knowledge and design procedures for Reverse Osmosis (RO) and Membrane Bioreactor (MBR) applications. WASDA was developed to provide available information to make appropriate decisions on wastewater treatment plant design. WASDA mainly focused on the municipal and industrial applications to produce conceptual and process design for secondary and advanced treatments. WASDA consists of multiple modules such as equalization, conventional activated sludge, extended aeration, sequencing batch reactor, oxidation ditch, rotating biological contactor and membrane system. Expert knowledge in the information base was assembled from design textbooks, manuals and other design requirements such as Department of Environment (DOE) and Department of Sewerage Services (DSS) and converted into Artificial Intelligence (AI) rules. The study provides a user-friendly approach to access essential knowledge about MBR and RO and the procedures to design MBR and RO, including design requirements, analysis of process performance and cost estimation. The performance of the WASDA for MBR system was verified based on case studies of an actual design of Kubota MBR process for industrial wastewater treatment plant in Malaysia and sewage treatment plant in Singapore by Chiyoda Kohan Co. Ltd. Keywords

Decision support system, industrial and domestic wastewater treatment, membrane bioreactor, reverse osmosis, WASDA.

INTRODUCTION

Decision Support System (DSS) is the most successful application of Management Support System (MSS) and have been used broadly in wastewater management field. DSSs are interactive computer-based tools used by decision makers since 1960s to help answer questions, solve problems and support, or refute conclusions (Hall, 2002). Over the past 30 years, DSS development has been used various concepts such as spreadsheets, databases, networks, hypermedia, expert systems (ES), visual programming, intelligent agents, neural networks, etc. (Beynon *et al.*, 2002). DSS are cheaper compared to human experts in the long-term scenario. Since early 1970s, DSSs have been proved to be a good tool to human since it can help them to identify problems faster, examine various alternatives, and make a choice. In an engineering field, DSS can assist engineer to solve calculation design in a short time compared to manual calculation. Previous studies showed that most of researchers used knowledge-based concept in developing a decision support system.

Membrane bioreactor (MBR) is an effective treatment technology for wastewater treatment and recycling, which consisting of suspended biomass and microfiltration membrane in a biological reactor. Presently it has been applied at full scale on certain industrial wastewater treatment and domestic wastewater recycling (Zhang *et al.*, 2003). Meanwhile, reverse osmosis (RO) has been widely used in industrial wastewater treatment (Ujang and Anderson, 2000).

WASDA in perspective

WASDA (<u>Was</u>tewater Treatment Plant <u>Design Advisor</u>) has been developed to be a decision support tool for design and process selection of wastewater treatment plant, in municipal and industrial sector. WASDA can support the production of conceptual and process design for primary, secondary and advanced treatments as proposed by best practices manuals or public authorities related to sewerage services or environmental control. The system includes design calculations, standard criteria, equipment selection, plans and specifications of various treatment units, which displayed as interactive graphic and user-friendly interfaces. MBR and RO modules are some of components provided in WASDA. The modules presented design calculation procedure and cost estimation based on theoretical consideration and standard criteria.

METHODS

System Plan

To maximize the use of MBR and RO module in WASDA, the system were assured to be user-friendly and accessible. For this project, the user interface was significantly distress on its function. The programming tool used to design the system is Visual Basic 6.0 and integrated with Microsoft Access. The MBR and RO modules were divided into two main parts, which are (a) information section and (b) design calculation worksheet. The architecture of the MBR and RO modules, mostly on design calculation worksheet was modularly planned as shown in Figure 1. The input, processing and output steps were implemented on each worksheet. The different between calculation worksheet of WASDA and Excel is the hidden formula to avoid errorness if users key-in incorrect data. When user entered the WASDA Main Menu, he/she could select menu at the top of window to access design calculation screen. All data can be entered into boxes at input frame. Conceptual layout of the process for MBR treatment also displayed at the data input screen. Moreover, RO module can perform calculation on costing included capital and operating cost.

System Analysis and Validation

System prototype for RO and MBR are quickly developed and well demonstrated to users because input is used to refine the WASDA. The main advantage is that the WASDA can quickly provide to users, even though it may not be ready for institutional use. Feedback can be obtained and the system can be modified by moving to the next prototype. In fact, further analysis may need to be performed as well.

A suitable verification and validation is then carried out. The WASDA at this stage is regularly being tested and validated by trial-and-error approach, which called 'What-if' analysis. "What-if' analysis is structured as "What will happen to the solution if an input variable, an assumption, or a parameter value is changed". For example, "What will happen to the volume of the aeration tank if the flowrate of the influent wastewater increases by 10 percent?"

Furthermore, verification has been done by comparing manual calculations with calculation using the WASDA and also by existing calculation tool such as Excel. A few sets of data will be produced and the comparison will be made using a descriptive statistic analysis.

Its performance was evaluated by performing a case study on the conceptual design for wastewater treatment plant in Malaysia. In the case of Membrane Bioreactor (MBR) System module, the test was based on *Process Design of Kubota MBR Process* for the project on *Factory Industrial Waste Water Treatment*.

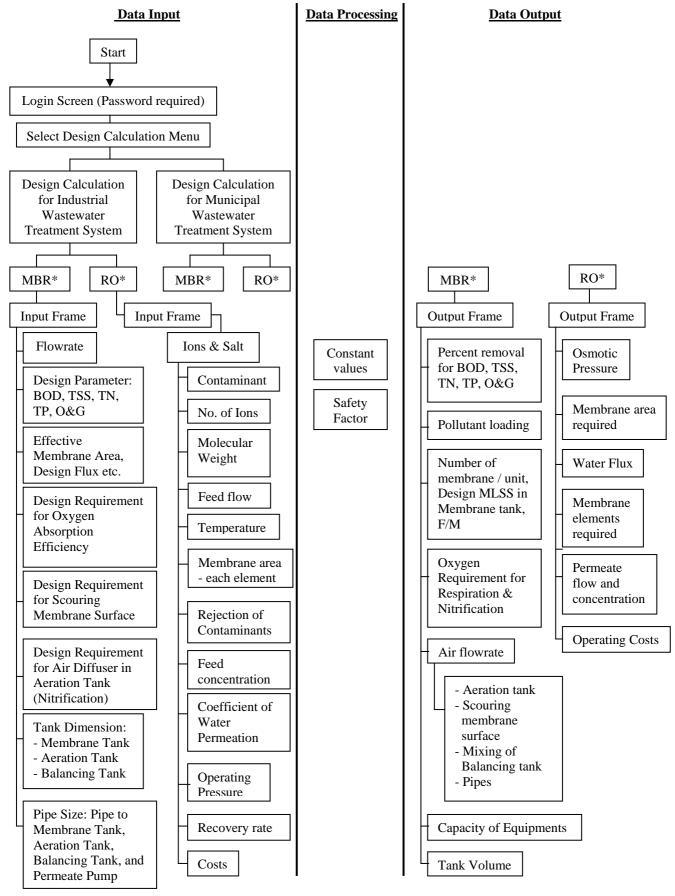


Figure 1. Architecture of WASDA – MBR and RO modules (Design Calculation Worksheet)

RESULTS AND DISCUSSION

WASDA modules including RO and MBR were presented as user-friendly screens with selection menus and buttons. As shown in Figure 2, once all input data are entered, the user can click the "Calculate" button and automatically the result appeared in "Output Frame". While, Figure 3 showed as a screen for cost estimation of RO treatment system. The "Design Flow" and "Conversion Unit" buttons were provided at the bottom of RO screen. This would allow user to access screen that can convert units for certain data such as feed flow, membrane area, plant capacity, production rate etc. The "Reset" button is used to rearrange the data to the standard setting when user wants to start a new calculation.

🛃 RO Unit Design Calculation - Ions & Salt 📉	Operating Costs Estimation
INPUT Contaminant Sodium Chloride No. of Ions 2 Molecular Weight 58.45 g/gmol	INPUT Plant Capacity 21600 gal/day Operating Pressure 300 psi Recovery Rate 80 %
Feed Flow 15 gal/min Feed Concentration 6000 mg/L Temperature 25 °C Coefficient of Water Permeation 1.9 x10 ⁻⁶ gmol/cm ² .s.atm	Energy Efficiency of Pump 80 % Recovery of Feed Pump by Energy Recovery Equipment 15 % Cost of Electricity 0.25 RMAWh
Membrane Area for Each 250 ft² Operating Pressure 300 psi Rejection of Contaminants 99 % Recovery Rate Required 80 %	Membrane Replacement Membrane Cost 500 RMm ² Membrane Production Rate 74.00 gal/m ² day Membrane Life 3 year
OUTPUT Stage 1 Osmotic Pressure 9 psi Water Flux 37.62 x10 -6 gmol /cm 2.s	Labour 6 Rh/hr Hours per Shift 0 hr/shift Shifts per Day 2 number/day Workers per Shift 2 number/dshift Labour overhead 15 %
Membrane Area Required 1506.01 ft ² Membrane Elements 6 Required	Spare Parts Cost for Spare Parts T RM / 1000 gal
Stage 2 Osmotic Pressure 18 psi Water Flux 36.46 x10 si Membrane Area Required 753.01 #2 Membrane Elements 3	Pretreatment and Posttreatment Cost for Chemical RM/1000 gal Other
Permeate (Product) Permeate Flow 12 gal/min Permeate Concentration 10.94 mg/L	Other Costs 1 RM/1000 gal OUTPUT Operating Costs 20.19 RM/1000 gal
Design Flow Conversion Unit Calculate Reset \$ Operating Costs	Calculate Reset Results Summary

Removal.

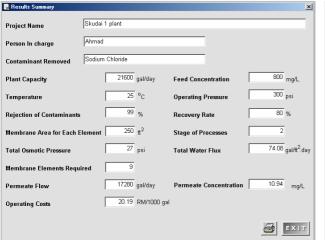
Figure 2. Calculation Screen for RO Module: Ions & Salt Figure 3. Cost Estimation Screen for RO Module: Ions & Salt Removal.

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If user satisfied with the calculation, the results summary can be displayed as shown in Figure 4. The results can be printed out by clicking the provided button. Besides of Design Calculation screen, there were Information screens that provided the essentials knowledge of membrane treatment process and operations as shown in Figure 5.

📕 Membrane Operat

The term membrane operation



he term membrane operation is recommended rather than the term membrane rocess. In general, a process is supposed to consist of two or more operations. A nembrane operation can be defined as an operation where a feed stream is divided -Type of Membrane Operations general classification can be obtained by considering the embrane operati llowing parameters Driving force • Pressure-Driven Membrane Operations These are membrane operations in which the driving force is a pressure difference across the membranes. 1. Reverse Osmosis (RO). Reverse osmosis is a pressure-driven membrane --1 Table: Comparison Between 4 Pressure-Driven Membrane Operations Permeation Operations These are membrane operations where the driving force is activity mixtures. When applied to solutions, it is the solvent which is transferred through the membrane. 1. Gas Permeation (GP) --Dialysis Operations These are membrane operations applied to solutions in which it is the solute which is transferred through the membrane. The driving forces is an activity or an electrical potential difference in the absence of any trans-membrane pressure difference. 1 -

Term Membrane Operations

Figure 4. Result Summary Screen for RO Module: Ions & Salt Removal.

Figure 5. Information Screen for RO module.

Figure 6 and 7 showed input boxes for estimated values such as flowrate; design parameters (BOD, TSS, T-N, T-P and O&G); effective membrane area; design flux and design requirements for oxygen absorption efficiency, for scouring membrane surface and air diffuser in aeration tank. Furthermore, estimated values that should be added at Input Screen (as displayed in Figure 7) were consisted of Tank Dimension (membrane tank, aeration tank and balancing tank) and size of pipes to membrane tank, aeration tank, balancing tank and also permeate pump. The Output Screen was appeared when user clicked the "Calculate" button as shown in Figure 8 and 9.

Based on these screens, the RO and MBR modules were not only allow users to find the best solution, but also enable the analysis of data when some input data was changed. These capabilities can also be used for minimization of capital and operating cost.

🛋 Design of Membrane Bioreactor - Industrial Wastewater Treatment (Part 1)	Design of Membrane Biornactor (MER) - Industrial Westewater Treatment (Part 2)	🛛
Fite Run Tools	File:	
Influent Origin of the second s	Air diffuser for aeration tank (nhtiffication) Pipe to Aeration Tank 40 Specific air flowrate 5 m ² /m Effective length of 65 Pipe to Aeration Tank 40	• mm • mm • mm
T. N 200 m mp1 T. P. WLSS is exception tank 10000 mp1 T. P. 200 m mp1 T. P. 10 mp1 WLSS is exception tank 10000 mp1 Old & Grease 600 m mp1 Old & Grease 10 mp1 2 s (gm3^3 q^1) Return Studge Return 3 Theoretical Tri removal 9 mp1 0.01	Acration Tank Member of tank 1 Length 4 00 m Size of discharge pipe 25 Wohn 1100 m Height 2 65 m 55 55 50 <td>• mm</td>	• mm
Drygen Absorption Efficiency Ateration Tank Water Depth 265 m M Water Depth 266 m m S absorption for water in zero DO 155 m % S absorption for water in zero DO 45 m % Ratio between % absorption for sludge & water 075 m Ratio between % absorption for sludge & water 065 m m in € Close to zee met Gala 2 in Save Next	Buncher of tank 1 Length 500 m initial Courts use need data Weigh 4.00 m Height 250 m Save Previou	p jr n Next

Figure 6. Input Screen for MBR module – Part 1.

TSS removed	9.6 6.7 6.7	C	% T.P removed % Oil & Grease remove	95 rd 98.3	s	Design MLSS in Membrane Tank Design BOD-SS Loading or F/M ratio	13333 0.2	mg1 d ⁻¹
Pollutant Loading 30D ^[52] kg/d Calculated Number of ^[7]	55	j20 pieces	kgid T-N Calculated Number of Unit	[6 [1	kg/d	Oxygen Requirement for Respiration and Nitrificati Quantity of BOD removed Oxygen used to provide energy for growth Oxygen used for endogenous respiration Oxygen total	26 [36 [196 [45.6	kgi kg kg kg
Air flow rate required for Total air flow rate Oxygen Transfer Rate	scourin	g mem	brarie surface	1.25	m³min kgid	Air flow rate required for aeration tank Oxygen for nitrification Air diffuser for nitrification tank Oxygen transfer rate	[31.91 [1.81	kg/d kg/d/p
DesignTank Volume Aeration Tank Theoretical tank volume HRT	e 17.1 22.9	_ m ³	Design volume	19.08	m ³	Required number of air diffuser and Required air flowrate	1	pcs m ³ mi
Membrane Tank Design volume	0.9		HRT	10.68				
Balancing Tank Design volume	50	m ²	HRT	60	ī.	Cick to see next data P PI Calculate Save	Previo	us Ne

Figure 8. Output Screen for MBR module – Part 1.

Figure 7. Input Screen for MBR module – Part 2.

UTPUT (b)		Capacity of Equipments	
Air Flow Rate for Mixing of Balancing Tank	^{[275} m ³ h [062 m ³ min	Wastewater 0.055 m ³ min Permeate p Feed Pump [1.25 m ³ min Aeration Bio blower	
Pipe Size			
Membrane Tank		Permeate pump	
Velocity of an air feed pipe to the membrane tank	10.6 m/s	Velocity in discharge pipe	0.5 m/s
Air flowrate	125 m ³ h	Flowrate in discharge pipe	0.015 m ³ /min
Balancing Tank			
Velocity of an air feed pipe to the balancing tank	8.2 m/s	Velocity in permeate suction pipe	lot m/a
Air flowrate	0.62 m ³ /h	searchy as between action here.	1
Aeration Tank		Flowrate in permeate suction pipe	0.015 m ³ /min
Velocity of an air feed pipe to the aeration tank	3.9 m/s		
Air flowrate	[175 m ³ /h	H Click to see next data + H Calculate	Save Print Previous
Inform	nong Tark 50 m ³	nn Bar Sceen Amaton Tark, Menbare Tart V 1300 m ² V 165 m ² Menbare Unit	

Figure 9. Output Screen for MBR module – Part 2.

CONCLUSION

The visual-based of the system represents WASDA as a support tool for conceptual design of wastewater treatment plants. Design calculation for MBR and RO treatment were dependent on many variables. In that case, the creation of RO and MBR modules in WASDA system is useful to assist design engineers and consultant for making decision on plant, process performance and cost estimation (typically based on standard requirements). The widely use of the system whether at desktop or laptop computers give more advantages to user for making decision on wastewater treatment plant design in a minimal time.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Universiti Teknologi Malaysia (UTM) for partly financing this study under Commercialization Fund (Vot 98255).

NOMENCLATURE

- BOD Biochemical Oxygen Demand (mg/l)
- TSS Total Suspended Solids (mg/l)
- TN Total Nitrogen (mg/l)
- TP Total Phosphorus (mg/l)
- O&G Oil and Grease (mg/l)

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