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Specialized Short Course on **MEMBRANE TECHNOLOGY** for Water and Wastewater Treatment

27 – 28 June 2009 (4 -5 Rajab 1430 H)

Prince Khalid bin Sultan Chair for Water Research
Civil Engineering Department, Hall 1 A 36
College of Engineering, King Saud University



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Lecture 8

Design Procedures for RO & MBR: WASDA as Decision Support System

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Presentation Menu

- Decision Support System
- DSS Objectives
- WASDA & MBR in brief
- Procedures
- Results
- GROUP ASSIGNMENT



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Decision Support System

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- Interactive computer-based tools used by decision makers since 1960s to help answer questions, solve problems and support or refute conclusions
- Concepts: Spreadsheets, databases, networks, hypermedia, expert systems, visual programming, intelligent agents, neural networks, etc.
- Potential to improve decision quality, competitive edge, time-saving and productivity when users have both sufficient technical knowledge of the system and enough experience of the job.
- Widely used for the solution of various engineering and management problems



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Learning Outcomes and Objectives

- WASDA as a decision support system for designing membrane processes
- Practice designing Reverse Osmosis (RO) and Membrane Bioreactor (MBR) systems.
- To perform tasks as consultants, design engineers and policy makers in relation to membrane processes



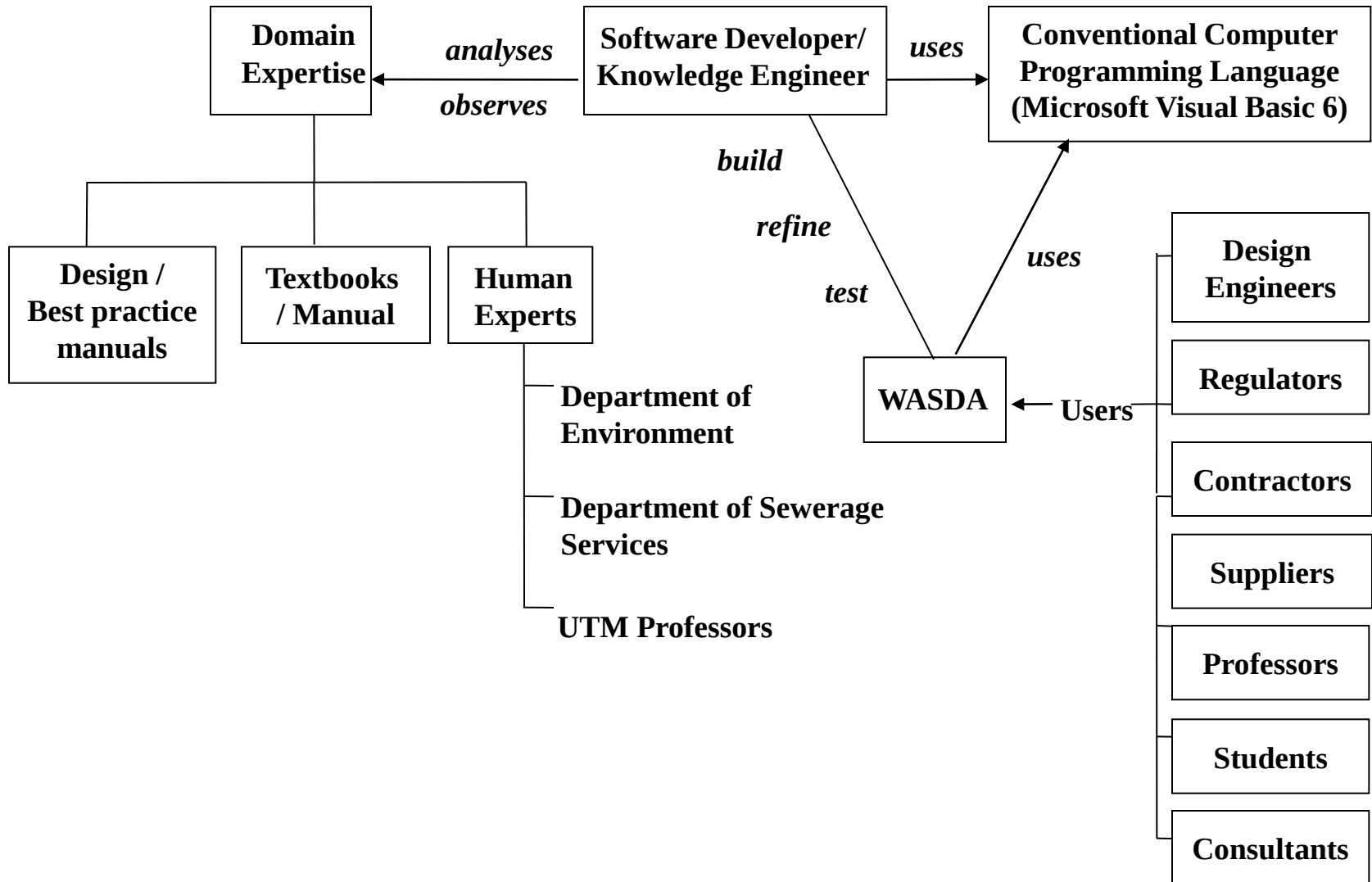
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WASDA in Brief

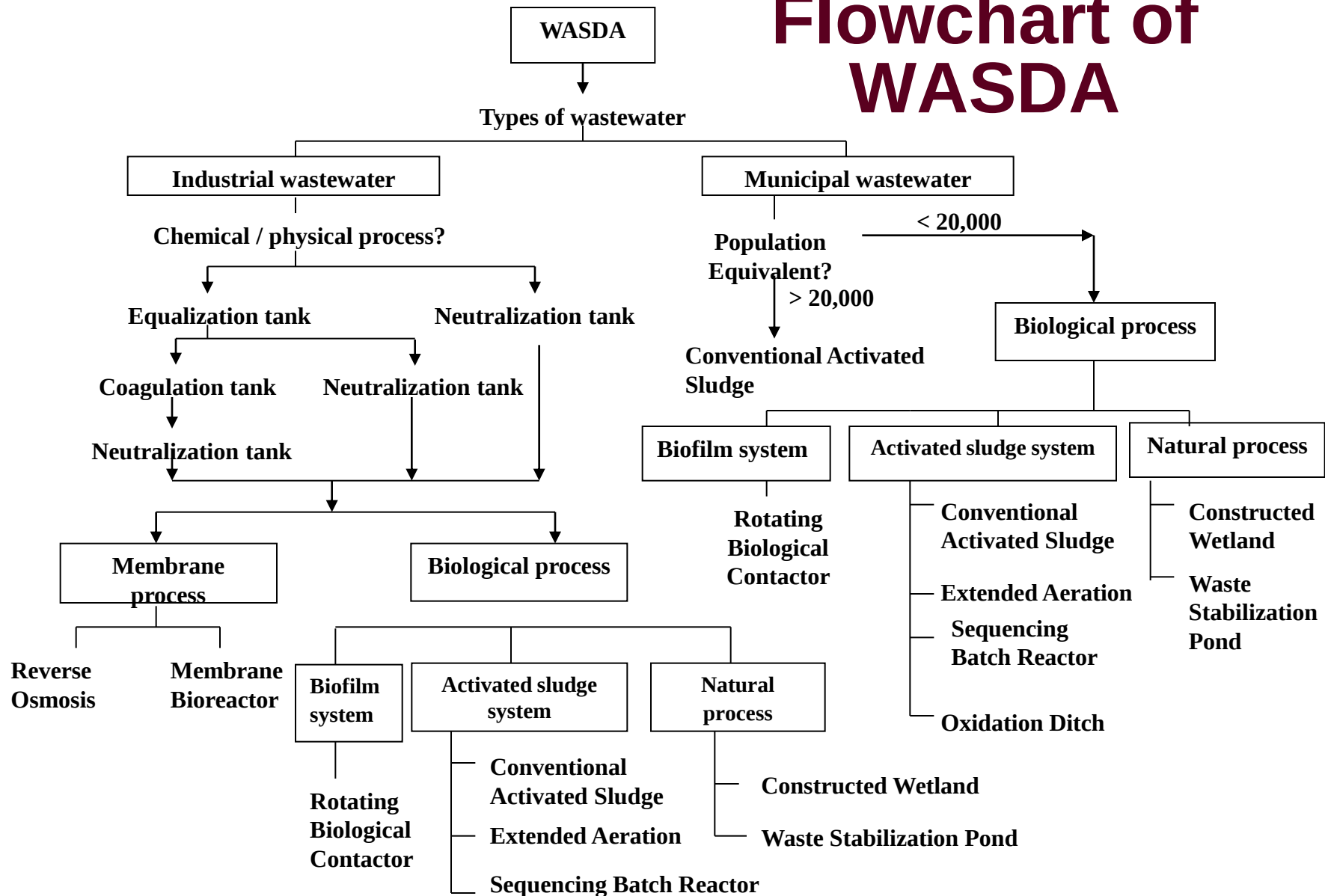
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- Wastewater Treatment Plant Design Advisor.
- DSS was developed by IPASA-UTM, esp. for wastewater treatment plant design and decision making
- Contains 2 main parts:
 - (a) Knowledge / information base
 - (b) Design calculation spreadsheet
- Provides conceptual & process design recommendations for conventional wastewater, primary, secondary & advanced treatments – proposed by best practical manuals / public authorities (sewerage services / environmental control).
- Mainly focused on municipal and industrial applications to produce conceptual and process design for primary, secondary and advanced treatments.

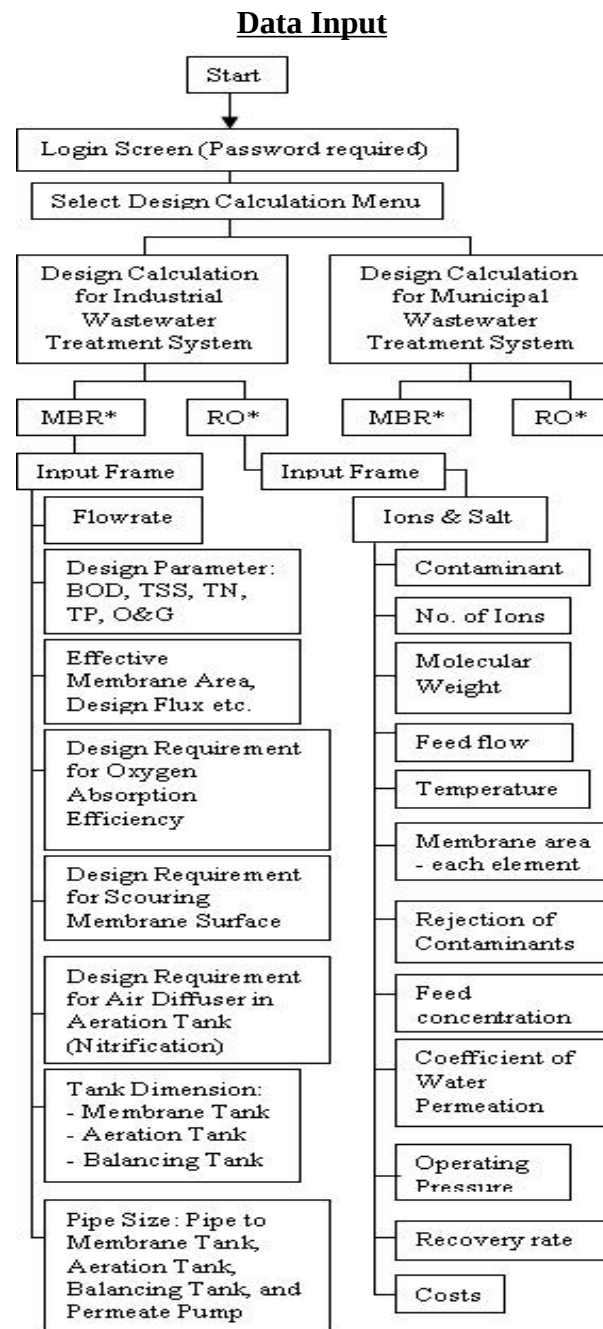
WASDA Development Process



Flowchart of WASDA



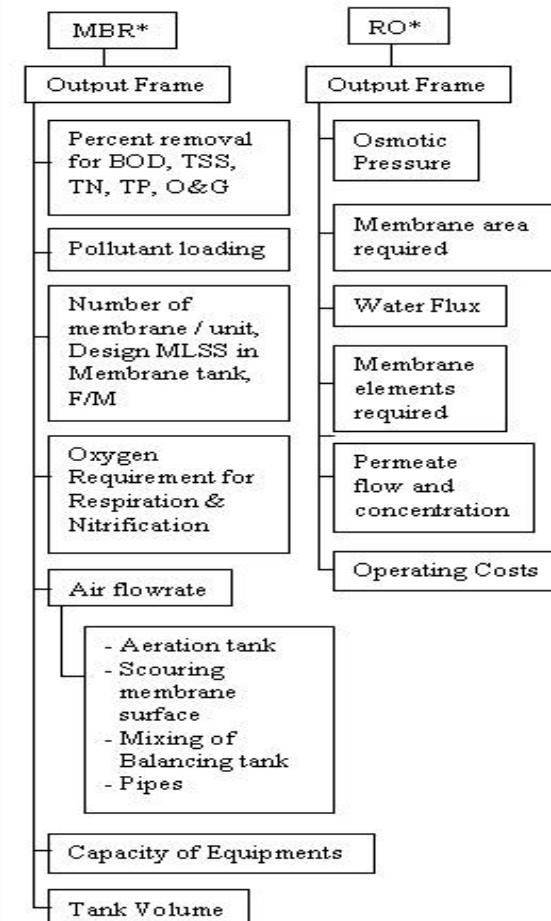
Achitecture of MBR & RO Modules



Data Processing



Data Output





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Design Procedures

Calculation
Screen for
RO Module:
Ions & Salt
Removal



RO Unit Design Calculation - Ions & Salt

INPUT

Contaminant	Sodium Chloride	No. of Ions	2	Molecular Weight	58.45	g/gmol
Feed Flow	15	gal/min		Feed Concentration	800	mg/L
Temperature	25	°C		Coefficient of Water Permeation	1.9	$\times 10^{-6}$ gmol/cm ² .s.atm
Membrane Area for Each Element	250	ft ²		Operating Pressure	300	psi
Rejection of Contaminants	99	%		Recovery Rate Required	80	%

OUTPUT

Stage 1

Osmotic Pressure	9	psi	Water Flux	37.62	$\times 10^{-6}$ gmol/cm ² .s
Membrane Area Required	1506.01	ft ²	Membrane Elements Required	6	

Stage 2

Osmotic Pressure	18	psi	Water Flux	36.46	$\times 10^{-6}$ gmol/cm ² .s
Membrane Area Required	753.01	ft ²	Membrane Elements Required	3	

Permeate (Product)

Permeate Flow	12	gal/min	Permeate Concentration	10.94	mg/L
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Navigation: Design Flow | Conversion Unit | Calculate | Reset | \$ Operating Costs

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Design Procedures

**Cost
Estimation
Screen for
RO Module:
Ions & Salt
Removal**



Operating Costs Estimation

INPUT

Plant Capacity gal/day Operating Pressure psi Recovery Rate %

Energy

Efficiency of Pump % Recovery of Feed Pump by Energy Recovery Equipment %

Cost of Electricity RM/kWh

Membrane Replacement

Membrane Cost RM/ft² Membrane Production Rate gal /ft² .day Membrane Life year

Labour

Labour Cost per Hour RM/hr Hours per Shift hr/shift Shifts per Day number/day

Workers per Shift number/shift Labour overhead %

Spare Parts

Cost for Spare Parts RM / 1000 gal

Pretreatment and Posttreatment

Cost for Chemical RM/1000 gal Cost for Filters RM/1000 gal

Other

Other Costs RM/1000 gal

OUTPUT

Operating Costs RM / 1000 gal

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Design Procedures

**Result
Summary
Screen for
RO Module:
Ions & Salt
Removal**



Results Summary

Project Name	Skudai 1 plant		
Person In charge	Ahmad		
Contaminant Removed	Sodium Chloride		
Plant Capacity	21600 gal/day	Feed Concentration	800 mg/L
Temperature	25 °C	Operating Pressure	300 psi
Rejection of Contaminants	99 %	Recovery Rate	80 %
Membrane Area for Each Element	250 ft ²	Stage of Processes	2
Total Osmotic Pressure	27 psi	Total Water Flux	74.08 gal/ft ² .day
Membrane Elements Required	9		
Permeate Flow	17280 gal/day	Permeate Concentration	10.94 mg/L
Operating Costs	20.19 RM/1000 gal		

 **EXIT**

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Other Info in WASDA

Information
Screen for
RO module →

Membrane Operations

Term Membrane Operations

The term membrane operation is recommended rather than the term membrane process. In general, a process is supposed to consist of two or more operations. A membrane operation can be defined as an operation where a feed stream is divided

Type of Membrane Operations

A general classification of membrane operation can be obtained by considering the following parameters:

1. 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


[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.





Design Results

Input Screen for
MBR module –
Part 1



Design of Membrane Bioreactor - Industrial Wastewater Treatment (Part 1)

File Run Tools

INPUT (a)

Influent

Average Flow m³/d Daily Maximum Flow m³/d

Design Parameter

Influent BOD	2600 mg/l	Effluent BOD	10 mg/l
TSS	1500 mg/l	TSS	50 mg/l
T-N	300 mg/l	T-N	10 mg/l
T-P	200 mg/l	T-P	10 mg/l
Oil & Grease	600 mg/l	Oil & Grease	10 mg/l

Return Sludge Ratio Theoretical T-N removal %

Critical flux m/d Average Design Flux m/d

Effective membrane area m²/pc

Working factor of suction pump

Type of membrane unit ES

Required number of cartridge pieces

MLSS in aeration tank mg/l

BOD volume loading kgm⁻³d⁻¹

Ratio between oxygen utilization & BOD removal

Endogenous respiration rate

Ratio of MLVSS to MLSS

Oxygen Absorption Efficiency

Aeration Tank

Water Depth m

% absorption for water in zero DO %

Ratio between % absorption for sludge & water

Membrane Tank

Water Depth m

% absorption for water in zero DO %

Ratio between % absorption for sludge & water

Click to see next data Save Next

Design Results

Input Screen
for MBR
module –
Part 2



Design of Membrane Bioreactor (MBR) - Industrial Wastewater Treatment (Part 2)

File

INPUT (b)

For scouring membrane surface
Air flowrate/cartridge 10 l/min.pc O₂ conc. of air (20 °C) 0.2683 kg/m³

Air diffuser for aeration tank (nitrification)
Specific air flowrate 5 m³/h Effective length of diffuser 0.5 m/pc

Tank Dimension

Aeration Tank
Number of tank 1 Length 4.00 m
Width 1.80 m Height 2.65 m

Membrane Tank
Number of tank 1 Length 2.8 m
Width 1.20 m Height 2.65 m

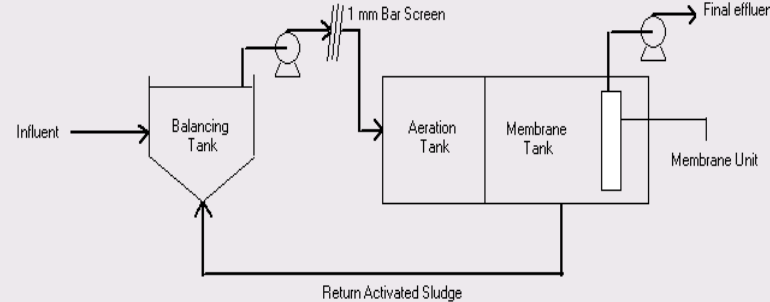
Balancing Tank
Number of tank 1 Length 5.00 m
Width 4.00 m Height 2.50 m

Pipe Size
Pipe to Membrane Tank 50 mm
Pipe to Aeration Tank 40 mm
Pipe to Balancing Tank 40 mm

Permeate Pump
Size of discharge pipe 25 mm
Size of suction pipe 50 mm

Click to see next data

Save Previous Next





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Design Results

Output Screen
for MBR
module –
Part 1



Design of Membrane Bioreactor (MBR) - Industrial Wastewater Treatment (Part 3)

File Run Tools

OUTPUT (a)

Design Parameter

% BOD removed	99.6	%	% T-P removed	95	%
% TSS removed	96.7	%	% Oil & Grease removed	98.3	%
% T-N removed	96.7	%			

Design MLSS in Membrane Tank: 13333 mg/l
Design BOD-SS Loading or F/M ratio: 0.2 d⁻¹

Pollutant Loading

BOD	52	kg/d	SS	30	kg/d	T-N	6	kg/d
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Calculated Number of Membrane: 125 pieces
Calculated Number of Unit: 1 unit

Air flow rate required for scouring membrane surface

Total air flow rate	1.25	m ³ /min
Oxygen Transfer Rate	13.69	kg/d

Design Tank Volume

Aeration Tank

Theoretical tank volume	17.1	m ³	Design volume	19.08	m ³
HRT	22.9	h			

Membrane Tank

Design volume	8.9	m ³	HRT	10.68	h
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Balancing Tank

Design volume	50	m ³	HRT	60	h
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Oxygen Requirement for Respiration and Nitrification

Quantity of BOD removed	52	kg/d
Oxygen used to provide energy for growth	26	kg/d
Oxygen used for endogenous respiration	19.6	kg/d
Oxygen total	45.6	kg/d

Air flow rate required for aeration tank

Oxygen for nitrification	31.91	kg/d
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Air diffuser for nitrification tank

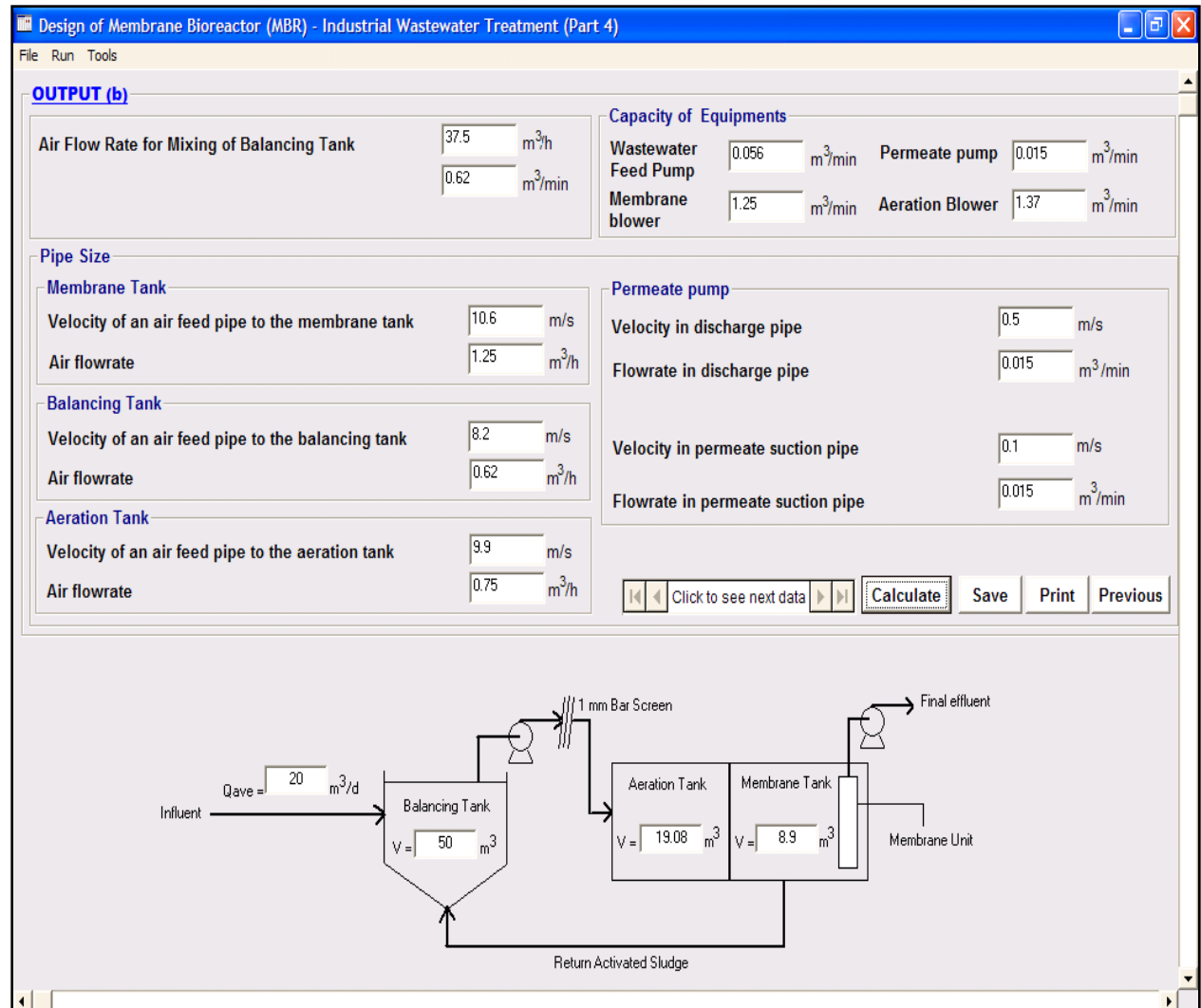
Oxygen transfer rate	1.81	kg/d/pc
Required number of air diffuser	> 18	pcs
Required air flowrate	> 0.75	m ³ /min

Click to see next data Calculate Save Previous Next

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Design Results

Output Screen
for MBR
module –
Part 2





Validation

RO Unit Design Calculation - Ions & Salt

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---------------	----	---------	------------------------	-------	------

Design Flow Conversion Unit Calculate Reset \$ Operating Costs

Change Operating Pressure to evaluate change in Water Flux

Reactor Volume



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Validation of Output: Descriptive Statistic Analysis

	Manual Calculation	WASDA
Mean	0.337785	0.337788
Standard Error	0.024246	0.024246
Median	0.341284	0.341287
Standard Deviation	0.059390	0.059390
Sample Variance	0.003527	0.003527
Kurtosis	-1.126304	-1.126312
Skewness	-0.213180	-0.213190
Range	0.158761	0.158762
Minimum	0.254017	0.254019
Maximum	0.412778	0.412781
Sum	2.026710	2.026726
Count	6.000000	6.000000

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Group Design Assignment

Problem statement:

Water resources for Seremban, Nilai and Port Dickson to are to be upgraded in terms of resource availability and water quality. The existing dams (3) are no longer sufficient to provide enough volume for 2010. There are 2 options to meet this requirements, and for upgrading for 2015:

1. A new dam which cost RM1.2 billion located in a reserved forest in Jelebu district, or
2. An advanced water treatment plant, located downstream of Sungai Linggi.

Task:

As a consulting group, you are assigned to evaluate the feasibility of using membrane systems. Your opinion will be evaluated in a group presentation session, based both on technical and financial aspects.