Membrane Bioreactors for Wastewater Treatment

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PDH: 4

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Acronyms and Abbreviations

BOD	biochemical oxygen demand
BOD_5	five-day biochemical oxygen demand
BP	back pulse
cm	centimeter
CAS	conventional activated sludge
CDHS	California Department of Health Services
CEL	Calscience Environmental Laboratory
CIL	cleaned in line
CIP	cleaned in place
COD	chemical oxygen demand
CSTR	continuously stirred tank reactor
DO	dissolved oxygen
DD	double deck
EBPR	enhanced biological phosphorus removal
EDC	endocrine disrupting compounds
ENRCCI	Engineering News-Record Construction Cost Index
F/M ratio	food to microorganism ratio
ft^2	square foot
gfd	gallons per square foot per day
g/L	grams per liter
gpd	gallons per day
gpm	gallons per minute
hr	hour
in	inch
kg	kilograms
L	liter
L/hr-m2	liters per hour per square meter
L/min	liters per minute
L/s	liters per second
mJ/cm^2	millijules per square centimeter
m^2	square meter
m^3	cubic meter
m^3/min	cubic meter per minute
m^3/day	cubic meter per day
MBR	membrane bioreactor
MF	microfiltration
mg	milligram
MGD	million gallons per day
mg/L	milligrams per liter
mg/L-N	milligrams per liter as nitrogen
min	minute

mL	milliliter
MLSS	mixed liquor suspended solids
MLVSS	mixed liquor volatile suspended solids
mm	millimeter
MPN	Most Probable Number
MWH	Montgomery Watson Harza
NaOCl	sodium hypochlorite
NCWRP	North City Water Reclamation Plant
ND	non-detect
NH_3-N	ammonia as nitrogen
NH_4Cl	ammonium chloride
NO_2-N	nitrite as nitrogen
NO_3-N	nitrate as nitrogen
NTU	Nephelometric Turbidity Units
NWRI	National Water Research Institute
O&M	operations and maintenance
OOS	out of service
PFU	plaque forming units
PLC	Programmable Logic Controller
PLWTP	Point Loma Wastewater Treatment Plant
PL Lab	Point Loma Laboratories
PO_4-P	Ortho-phosphate as phosphorus
PO_4	ortho phosphate
ppm	parts per million
psi	pounds per square inch
QA/QC	quality assurance/quality control
RAS	return activated sludge
Reclamation	Bureau of Reclamation
RO	reverse osmosis
RR	recycle ratio
s	seconds
scfm	standard cubic feet per minute
SBWRP	South Bay Water Reclamation Plant
SDI	silt density index
TDS	total dissolved solids
TFC	thin film composite
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TP	total phosphorus
TSS	total suspended solids
UF	ultrafiltration
UV_{254}	ultraviolet absorbance at 254 nanometer
UVT	ultraviolet transmittance
VFD	variable frequency drive
VSS	volatile suspended solids
WAS	waste-activated sludge

Symbols

∆π	Net Osmotic Pressure of the Feed and Permeate
ºC	Degrees Celsius
$K	Thousands of Dollars
µg	Microgram
µmhos	Micromhos
µm	Micron
πf	Osmotic pressure of the feedstream (psi)

Calculated Parameters

HRT	Hydraulic Retention Time (hours)
IAF	Integrated Averaging Factor
J	Membrane Flux (gfd)
J@20ºC	Temperature Corrected Membrane Flux (gfd)
J_{SP}	Specific Flux (gfd/psi)
P_{NET}	Net Operating Pressure (psi)
Q_{NET}	Net Permeate Rate (gpm)
R	Salt Rejection (%)
RR	Recycle Ratio
SRT	Sludge Retention Time (days)
$SRT_{7\text{-day}}$	Average Sludge Retention Time over 7 days
TMP	Transmembrane Pressure (psi)

1. Executive Summary

Wastewater reclamation is gaining popularity worldwide as a means of conserving natural resources used for drinking water supply. The use of membrane bioreactor (MBR) technology, which combines conventional activated sludge treatment with low pressure membrane filtration, has been proven to be a feasible and efficient method of producing reclaimed water. The membrane component of the MBR process eliminates the need for a clarifier and is performed using low-pressure membranes such as microfiltration (MF) or ultrafiltration (UF). MBR technology offers several advantages to conventional wastewater treatment including reduced footprint, consistent and superior effluent water quality and ease of operation. For many areas, it is necessary to further treat reclaimed wastewater to reduce its inherent salinity making it useable for irrigation and industrial use. The superior effluent water quality of the MBR process makes it suitable for further treatment by reverse osmosis (RO) membranes as a final polishing step in reducing the salinity of reclaimed water.

The City of San Diego and its research consultant, Montgomery Watson Harza, MWH, have been evaluating the MBR process through various research projects since 1997 (Adham et al., 1998, 2000, 2001). Previous research has primarily focused on the feasibility of using MBR technology to produce reclaimed water. In 2001, the City of San Diego was awarded a cooperative agreement by the Bureau of Reclamation to further evaluate the MBR technology for its potential application to water reclamation. The main purpose of the study was to evaluate several leading manufacturers in an effort to encourage competition within the MBR industry. In addition, the study focused on optimizing MBR operation for water reclamation. Accordingly, the project team performed a parallel comparison of four leading MBR suppliers including US Filter Corporation/Jet Tech Products Group, Zenon Environmental, Inc., Ionics/Mitsubishi Rayon Corporation, and Enviroquip Inc./Kubota Corporation.

The four MBR systems were evaluated at the pilot-scale level while operating on wastewater from the Point Loma Wastewater Treatment Plant (PLWTP) located in San Diego, CA. Phase I testing consisted of the operation of the Kubota and US Filter MBR systems on raw wastewater for over 3,500 hours (146 days) and operation on advanced primary effluent for over 1,200 hours (50 days). During Phase II testing, the Zenon and Mitsubishi MBR systems were operated on advanced primary effluent for over 4,000 hours (187 days). As part of Phase I testing, effluent from the Kubota MBR system was further treated using reverse osmosis (RO) membranes provided by two leading RO manufacturers. The RO membranes were operated for over 1,700 hours (70 days) and 780 hours (32 days) with Kubota MBR effluent produced from raw wastewater and advanced primary effluent, respectively. The RO pilot unit consisted of two single pass trains, which were configured to allow operation at 50 percent recovery. Based on results of this testing, the project team is confident that RO membranes operating on MBR effluent could be successfully operated with a recovery between 75 percent to 90 percent which is the typical operating range for brackish groundwater.

The MBR systems tested were evaluated for their ability to produce high quality effluent and to operate with minimum fouling for a reasonable time between chemical cleanings. Furthermore,

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