SUSTAINABLE WATER MANAGEMENT: A FEASIBILITY STUDY OF RECYCLING TREATED INDUSTRIAL AND SANITARY WASTEWATER TO REUSABLE WATER

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ABSTRACT

Semiconductor companies are actively addressing the environmental impact of their business practices, with sustainability now playing a vital role in the industry. Different strategies were explored by onsemi Carmona to support Sustainable Development Goals (SDG) by United Nations (UN), to contribute to the Net Zero by 2040, and to address limited water sources of the plant. One of the strategies performed was by checking the feasibility of recycling effluent (treated wastewater) from Sanitary Treatment Plant (STP) and Wastewater Treatment Plant (WTP) to produce water for industrial purposes using Water Recycling System (WRS). The WRS consisted of three processes namely Multimedia Filtration (MMF), Activated Carbon Filtration (ACF), and Reverse Osmosis (RO). The water quality of WRS product was evaluated and showed conductivity, hardness, and silica content was lower by 93.40%, 99.93%, and 46.33% from the desired quality which showed that the WRS could produce water of better quality than anticipated. WRS operations controls were also looked to ensure WRS reject quality is compliant to the Department of Environment and Natural Resources (DENR) standard on water discharge quality.

1. 0 INTRODUCTION

Humans particularly use freshwater for daily needs, be it as potable water, domestic or industrial use. About 98% of freshwater sources can be found above ground as ice glaciers and below ground in earth's water table. Water readily available in lakes and rivers is what composes the remaining 2% freshwater source. The primary water source is the earth's water table or well water. High population growth and continuous pursuit of economic growth via urbanization causes the increasing water demand. Consequently, the demand rate surpasses the regeneration rate of the well water. Should this continue, there is an impending worldwide water scarcity from earth's water table. Though freshwater is still available in rivers and lakes, another problem arises: the quality of water is not that potable for use. This is where proper wastewater treatment and water management comes in. [1]

Studies have shown that treated wastewater can also be reclaimed, reprocessed, and recycled back for different purposes (i.e. irrigation, agricultural, industrial, recreational, etc.). Alleviating water scarcity via water recycling is an aspect that has not yet been fully utilized, explored, and maximized because of the general thinking of mankind that it is not safe for human consumption. Evolving technologies in water processes is the key to providing clean and safe water despite it coming from wastewater.[2]

The rapidly expanding semiconductor manufacturing industry has stringent water quality regulations and a high demand for water.[3] Water consumption of semiconductor companies in 2021 was measured around 10^6 m^3 ranging from 2.3 to 163.7x10^6 m^3. Figure 1 shows the energy usage and water withdrawal of the 27 semiconductor manufacturing companies with Samsung, SK Hynix, TSMC, Intel, and Micron as the top consumers of energy and water withdrawal.[4]

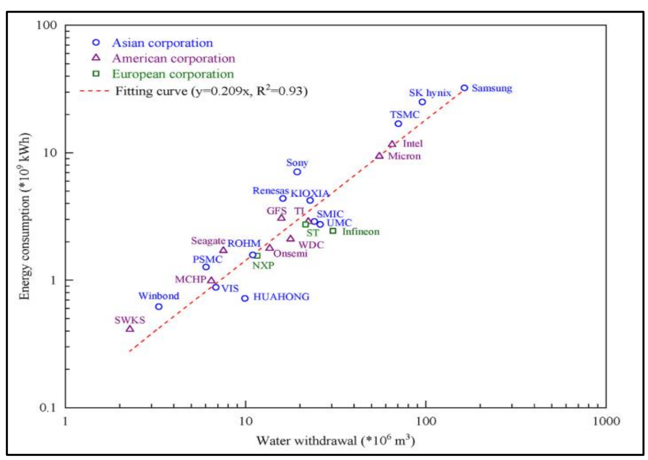

Fig. 1. Energy consumption and water withdrawal of selected semiconductor companies. This shows 2021 data of energy and water consumption of some semiconductor companies.

In onsemi Carmona, considering the water quality of the Philippines, only 40% of the water feed is converted into high purity water; the remaining 60% just goes to waste. Source of water is deepwell (or well water) and draw-out is limited by NWRB (National Water Resources Board); maximum is 10L/s (864 m^3/day). The limit has been maximized already and the local water district had confirmed the lack of capacity to support water needs of the site. Water delivery has been opted to augment the water demand to ensure compliance to deep well draw out limit –however, this option is costly (PHP 418.25 per cubic meter).

As an ethical company committed to legal compliance and to the company's NetZero by 2040 goals which is aligned with the SDG, this paper aimed to explore the feasibility of recycling STP and WTP effluent using rental WRS to provide additional water for industrial use.

2. 0 REVIEW OF RELATED WORK OR LITERATURE

Given the huge amount of water required for the manufacturing companies not just in semiconductor industry, but all over the world, it is vital that recovery of industrial and domestic wastewater effluent is considered to maximize potential water recycling capability of a plant. Many water utilities have difficulties meeting the regular water demand due to the rapidly depleting freshwater resources and deteriorating water infrastructure in many urban and rural areas. [5] Offering alternate sources of water is the primary strategy used by the water companies to address water scarcity.

To reduce water consumption and production costs, a water recycling system was installed by a semiconductor company in Singapore according to Ming Wu in 2003. The water recycling system composed of Pre-filtration, Ultrafiltration (UF), Ion exchanger, then followed by Ultraviolet (UV) filter, this successfully generated low-grade high-purity water (HPW) at a rate of 4.5 m^3/h from wafer saw and backgrind wastes, achieving an overall recovery rate of 90%. [6]

Several earlier studies have tried to maximize the efficiency of semiconductor wastewater treatment by applying physical, chemical, biological, or combination procedures. However, compared to other wastewater from other manufacturing industries, studies on semiconductor effluent are less advanced. Therefore, studies on semiconductor wastewater treatment methods are necessary to explore potential water sustainability. [8]

Water contains various types of impurities, including suspended and dissolved solids, microbiological, and other pathogen contaminants. To assess its quality, both physical and chemical tests are necessary. Turbidity, pH, color, odor, TDS (total dissolved solids) are some of the parameters used to check physical characteristics of water via physical tests. While BOD (biological chemical demand), COD (chemical oxygen demand), DO (dissolved oxygen), alkalinity, hardness, silica, and other substances found in natural waters involve chemical tests. The testing of water involves evaluation of the mentioned physicochemical parameters. The selection of parameters for water quality testing depends entirely on the intended purpose of water usage and the desired level of purity of water. [8]

RO is a water purification technique that relies on a semipermeable membrane. It effectively eliminates ions, proteins, and organic compounds that are challenging to remove through alternative methods. It is commonly used by water treatment facilities from desalination to pharmaceutical industries to produce pure water. However, RO needs pre-treatment to protect the RO membrane and extend its lifespan. Common pre-treatment used in water industry are MBR (Membrane Bioreactor), UF (Ultrafiltration), and MMF-ACF (Multimedia Filter & Activated Carbon Filter). [9]

According to the National Water Resources Board (NWRB), Section 44 for Qualification and Requirements of Well Drillers, Figure 2 below shows the limitations for the rate of withdrawal according to the distance of well installed. As part of onsemi Carmona's compliance to NWRB, deep well installed in the plant are being monitored and limited to 10 L/s.

RATE OF WITHDRAWAL IN LITERS PER SECOND	MINIMUM DISTANCE BETWEEN WELLS IN METERS
2 – 10	200
More than 10 – 20	400
More than 20 – 40	600
More than 40	1000

Fig. 2. NWRB withdrawal limit for well drillers. This shows the requirements that NWRB set in Sec. 44 of the Water Code of the Philippines.

onsemi Carmona has existing water reuse systems limited only to toilet flushing. The recycling rate is about 8% based on 2023 data. The system reuses treated wastewater from Metal Finishing and Wafer Saw in Plant 1 and RO reject in Plant 2.

3.0 METHODOLOGY

3.1 Plan

The objective of this project was to explore the feasibility of recycling wastewater effluent and use it for industrial purposes. Desired parameters for the WRS product quality were identified as shown in Table 1. The basis of the desired parameters was the water quality of the deep well water of the plant.

Table 1. Desired WRS Product Water Quality.

Parameter	Product water (desired)
pH	6.5 to 7.5
Total Hardness, mg/L	<100
Silica, mg/L	<100
Conductivity, uS/cm	<600

3.2 Do

Three critical points for water sampling were identified:

1. Effluent tank. It contains a combined WTP and STP effluent which will be the feedwater of the WRS. The result of the testing was used as design basis of the WRS to achieve product quality identified in Table 1.
2. WRS RO product tank. Testing results were used to qualify if desired parameters for the product water were achieved using the WRS system.
3. WRS RO reject line. This is the new effluent discharge point. Testing results were used to check if this is compliant to the DENR effluent standard in Appendix A.

Samples from these points were gathered in 1-liter sampling bottles and quality of each sample was checked to provide the data needed for the analysis. Quality checking was done using testing kits for pH, hardness, silica and conductivity.

3.3 Check

The test results of the effluent tank sample were used as baseline quality of feedwater. Using feedwater quality and simulation software that allows users to design RO systems, the design of the WRS system was generated. Once the system was installed and commissioned, the quality of product water was tested and compared with the desired product water quality identified in Table 1. It was compared using the percent error formula below. [10]

$$\%\ error = \frac{Desired\ value - Actual\ value}{Desired\ value} x100\% \qquad (1)$$

The quality of WRS reject was compared to the DENR DAO 2016-08 and 2021-19 (see Appendix A) to ensure that the quality of the plant effluent is within the required limit. This will provide data for the company's legal compliance to water discharge.

3.4 Act

Upon commissioning of the system, operational controls of the WRS were adjusted accordingly to meet quality requirements both for the product and the reject i.e. recovery rate, feedwater quality (e.g. conductivity, chlorine), flow rate, and pressure.

To sustain the quality of the product and reject water, system controls were established. These controls include sensors and scheduled maintenance activities.

4.0 RESULTS AND DISCUSSION

Feedwater of the water recycling is a mix of WTP and STP effluent. It is important to note that these are already treated wastewater and had met the DENR standards for wastewater discharge to bodies of water even without the WRS. In designing water treatment systems, knowing the quality of the water to be treated and the desired quality of the product is necessary. This will help in identifying what type of equipment and the capacity of equipment to use. The desired quality of the product is simple: it must have the same quality as deep well water. Additionally, the quality of the system reject must be compliant with local regulations.

4.1 Feedwater quality

There were four critical parameters checked in the feedwater which is shown in Table 2: pH, hardness, silica, and conductivity. Feedwater pH was at 7.4 which means that it was almost neutral in nature; same as that of pure water. Total hardness and silica were at 150mg/L and 100mg/L, respectively. Both were near the target levels, so treatment needed for removal of these parameters was very minimal. The most challenging parameter to decrease was the conductivity giving a value of 1600uS/cm when the requirement was just 600uS/cm.

Table 2. Water Recycling System Feedwater and Product Water Quality.

Parameter	Unit	Feed water	Product water (desired)
pH	-	7.4	6.5 to 7.5
Total Hardness	mg/L CaCO3	150	<100
Silica	mg/L	100	<100
Conductivity	uS/cm	1600	<600

There were multiple systems that can be utilized in recycling this kind of effluent. Three options were considered and based on assessment as shown in Table 3, the MMF-ACF-RO was identified as the best and fastest option.

Table 3. Comparison of WRS Design Options.

	MBR	UF-RO	MMF-ACF-RO
Lead time	long	long	**fast**
Cost	high	high	**low**
Space	low	mid	mid
Efficiency	high	mid	mid

Process flow of the WRS using MMF-ACF-RO is shown in Figure 3. MMF reduces the level of total suspended solids (TSS or turbidity level) such as silt, clay, grit, organic matter, algae, and other microorganisms found in STP. ACF removes contaminants, organic matter, and residual disinfectants. RO rejects dissolved and suspended materials. RO permeate, or product is pure water.

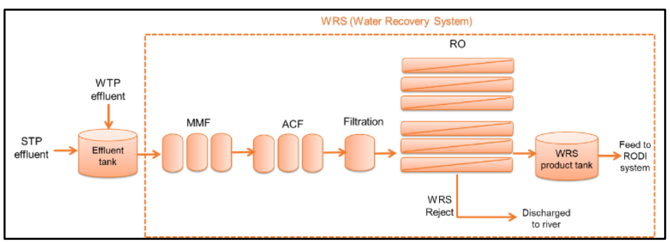

Fig.3. Process flow diagram of the WRS design. This shows how the STP and WTP effluent is being processed in the WRS.

4.2 WRS product quality

The designed recovery rate of the WRS was 60 to 65%. It was set to run at 60% recovery upon commissioning, about 92% of maximum design. Figure 4, 5, and 6 showed a 2-week data comparing water quality of the Effluent Tank and the product of WRS.

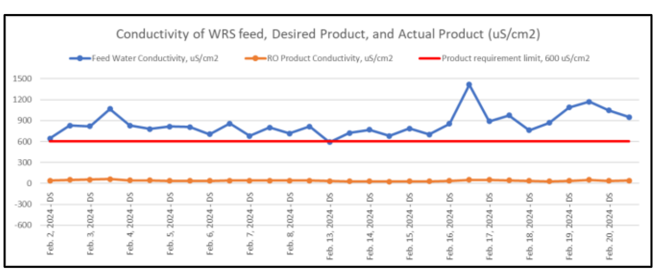

Fig. 4 Comparison of conductivity from WRS feed, desired product, and actual product. The WRS has significantly reduced the feed water conductivity below the desired.

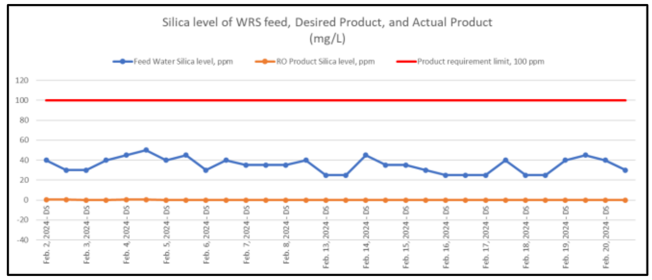

Fig. 5. Comparison of silica level from WRS feed, desired product, and actual product. Feed water silica level is already within the desired level but WRS further reduced the silica level to zero.

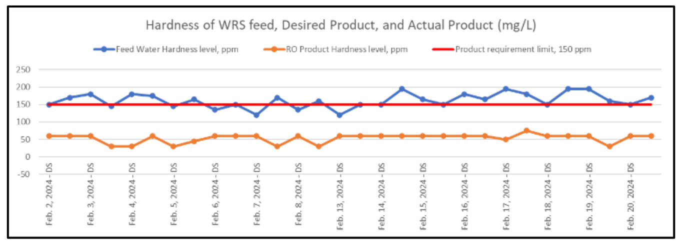

Fig. 6 Comparison of hardness from WRS feed, desired product, and actual product. The WRS has significantly reduced the feed water hardness below the desired.

WRS produced a better quality of water than the desired quality in terms of conductivity, silica and hardness with a percent error of 93.4%, 99.93% and 46.33%, respectively, as shown in Table 4. The product water pH was 5.6% lower than desired. Unlike conductivity, silica, and hardness, product water pH can be easily corrected using chemical dosing. With that, the product was still transferred to its tank because it will be corrected in the RODI process.

Table 4. Percent error of desired and actual product quality.

Parameters	WRS desired product	WRS actual product	% error
pH	6.5	6.13	5.6
Conductivity	600	39.62	93.40
Silica	100	0.07	99.93
Hardness	100	53.67	46.33

4.3 WRS reject quality

Rejected water in the system (WRS reject) is being discharged to the nearby body of water; therefore, it must meet the standard of the government on effluent water quality based on DENR DAO 2016-08 and 2021-19 (Appendix A). As shown in Appendix B, there were two parameters that consistently failed: copper and sulfate. Copper only came from WTP effluent while sulfates were from both WTP effluent (due to sulfuric acid injection) and STP effluent (due to aluminum sulfate injection). Since chemical injection (sulfuric and aluminum sulfate) could not be adjusted because it is system demand for effective treatment, the WRS operations were adjusted to pass these parameters.

The recovery rate of the system was adjusted from 60% to 55%. Upon adjustment, a sample of WRS reject was gathered again to see if there are changes in the quality. All parameters particularly sulfate and copper passed the March 6, 2024, sampling, as shown in Appendix C and D. The operation of the WRS is then maintained at 55% recovery rate which is 85% of the designed recovery rate. In this recovery rate, compliance to the government requirement based on water discharge is ensured.

4.4 Process controls

The WRS has proven that effluent water can be treated further and can produce water better than deep well water provided that standard maintenance activities are in place:

1. Backwashing of MMF and ACF at 10 psi differential pressure
2. Filter replacement at 10 psi differential pressure
3. Chemical cleaning of RO membranes at 20 psi differential pressure
4. Flushing of RO membranes
5. Chemical refilling and preventing the lack of chemical in the system as chemicals specifically biocide and antiscalant prevent immediate clogging of RO membranes.

These maintenance activities if not done will immediately decline the efficiency of the system thus giving low flow or low product water volume.

Additionally, the sensors (i.e. chlorine, level, flow, conductivity, and pressure) installed in the WRS were also protecting the system's efficiency and integrity. Conductivity and chlorine sensors were programmed to stop the system operations when conductivity is beyond 1600uS/cm which is the baseline quality of feed water and when chlorine is above 0.5mg/L because high chlorine levels easily destroy the integrity of RO membranes. These sensors must be of the highest accuracy and consistency through regular inspection and scheduled calibration.

Lastly, regular monitoring of the system and its critical parameters such as pH, conductivity, flowrate, and pressure is performed. If any of these parameters fail to meet the operating requirements, immediate troubleshooting must be done.

4.5 Results

The system had processed 91,611.30 m^3 of feedwater and produced 36,087.85 m^3 (40% recovery) from February to April 2024 as shown in Table 5. This does not include the product water used for RO flushing, a schedule flushing of membranes for maintenance purposes, which is about 8.9% of the feed water.

Table 5. Monthly feed water and product volume of WRS.

Month/Year	Feed Volume, m^3	Product Volume, m^3
Feb 2024	22,169.16	9,523.58
Mar 2024	32,815.53	12,407.89
April 2024	36,626.61	14,156.37
TOTAL	**91,611.30**	**36,087.85**

The system has generated a total savings of PHP 5.2M ($94.18K) from February to April 2024 and has a potential cost savings of PHP 22.7M ($406K) for one year by eliminating water deliveries.

Using rental WRS, cost per cubic meter of water dropped to PHP 158.01 ($2.87) from PHP 418.25 ($7.6) per cubic meter of delivered water (Appendix E). Furthermore, acquiring a permanent system has a potential reduction in cost per cubic meter.

5.0 CONCLUSION

This paper showed the feasibility of reprocessing WTP and STP effluent to address limited water sources of the plant and how the WRS (MMF-ACF-RO system) can produce water quality qualified for industrial purposes (WRS product) while still being compliant to legal requirements (WRS reject). Based on water quality results, the WRS product has better water quality in terms of conductivity, hardness, and silica content that is lower by 93.40%, 99.93%, and 46.33%, respectively, from the desired quality. This showed that the WRS could produce water of higher quality than anticipated.

In the 2022 sustainability report of onsemi (refer to Appendix F), increasing water recycling rate in manufacturing while minimizing total water demand is one of the top identified priorities. WRS plays a vital role in the commitment of onsemi to contribute to this priority, to SDG and to Net Zero by 2040. According to Dycian [11], one cubic meter of water consumed generates 10.6 kg of carbon emissions. During the 3-month operation of the WRS, it has recycled 36,087.85 m^3 water equivalent to 38,243.21 kg of carbon emission reduced.

6.0 RECOMMENDATIONS

Since the capability of the WRS to produce water with good quality has been proven, it is recommended to keep the WRS as a permanent system once the rental contract has expired. This will provide cost savings by eliminating rental cost, guarantee legal compliance, support sustainability goals of the company and protect the environment.

7.0 ACKNOWLEDGEMENT

Our deepest gratitude goes to our Facilities Department Manager, Nicasio Bordeos Jr. Your expertise, support, encouragement, and valuable feedback have been instrumental in shaping the quality of this technical paper. We also extend our thanks to the Water Operations team, our technicians, and operators, who ensured the smooth operation of the water system of the plant while we were in the process of creating this technical paper. Lastly, we want to extend our appreciation to the entire Facilities team for their unwavering support and insightful discussions which also helped enrich the content of this paper.

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9.0 ABOUT THE AUTHORS

Ma. Clarize Venerable is a chemical engineer from the University of the Philippines – Los Baños. She was a former laboratory analyst doing quality checking of water and wastewater. She also worked as a field service engineer in water treatment facilities in different industries (power, oil and gas, food and beverages). She has been in onsemi for four years heading the Water Operations section of the Facilities Department.

Joelenne Nikkie Galang is a recent graduate of Mapua University with a degree in Chemical Engineering. She was part of the 2022 New College Program of onsemi and was absorbed by the company after the program.

10.0 APPENDIX

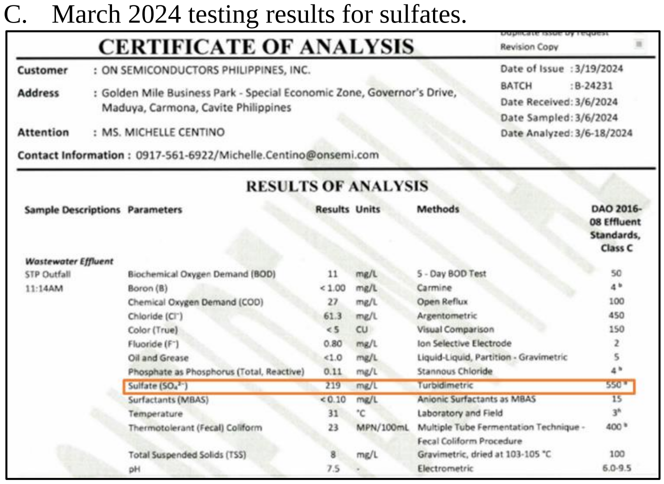
A. DENR DAO 2016-08/2021-19 effluent standard requirement.

	PARAMETER	DAO 2016-08 / 2021-19
1	pH	6.0 - 9.5
2	Color	150 TCU
3	Temperature	ºC
4	Biochemical Oxygen Demand	50 mg/L
5	Chemical Oxygen Demand	100 mg/L
6	Total Suspended Solids	100 mg/L
7	Oil & Grease	5 mg/L
8	Surfactants (MBAS)	15 mg/L
9	Copper	*1 mg/L
10	Zinc	4 mg/L
11	Boron	*4 mg/L
12	Chloride	450 mg/L
13	Fluoride	2 mg/L
14	Phosphate	*4 mg/L
15	Sulfate	550 mg/L
16	Thermotolerant (Fecal) Coliform	400 MPN/100mL
17	Nitrate, NO3 - N	14 mg/L
18	Ammonia, NH3 - N	*4 mg/L

B. WRS reject quality.

Parameter	**DENR requirement**	**Sampling Date**	
		Feb. 8	Feb. 20
pH	6.0 - 9.5	7.1	8.0
Color	150 TCU	10	<5
Temperature	ºC	30	25
Biochemical Oxygen Demand	50 mg/L	6	-
Chemical Oxygen Demand	100 mg/L	78	15
Total Suspended Solids	100 mg/L	2	5
Oil & Grease	5 mg/L	<1.0	-
Surfactants (MBAS)	15 mg/L	<0.10	<0.10
Copper	*1 mg/L	6.879	1.333
Zinc	4 mg/L	0.133	0.099
Boron	*4 mg/L	<1.00	<1.00
Chloride	450 mg/L	124.9	174.3
Fluoride	2 mg/L	1.13	1.17
Phosphate as Phosphorus	*4 mg/L	0.09	0.12
Sulfate	550 mg/L	589	655
Thermotolerant (Fecal) Coliform	400 MPN/100mL	350	<1.8
Nitrate, NO3 - N	14 mg/L	1.26	1.48
Ammonia, NH3 - N	*4 mg/L	1.46	1.07

C. March 2024 testing results for sulfates.



CERTIFICATE OF ANALYSIS

Revision Copy

Customer : ON SEMICONDUCTORS PHILIPPINES, INC.
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Attention : MS. MICHELLE CENTINO
Contact Information : 0917-561-6922/Michelle.Centino@onsemi.com

Date of Issue : 3/19/2024
BATCH : B-24231
Date Received: 3/6/2024
Date Sampled: 3/6/2024
Date Analyzed: 3/6-18/2024

RESULTS OF ANALYSIS

Sample Descriptions	Parameters	Results	Units	Methods	DAO 2016-08 Effluent Standards, Class C
Wastewater Effluent					
STP Outfall	Biochemical Oxygen Demand (BOD)	11	mg/L	5 - Day BOD Test	50
11:14AM	Boron (B)	< 1.00	mg/L	Carmine	4 ᵇ
	Chemical Oxygen Demand (COD)	27	mg/L	Open Reflux	100
	Chloride (Cl^-)	61.3	mg/L	Argentometric	450
	Color (True)	< 5	CU	Visual Comparison	150
	Fluoride (F^-)	0.80	mg/L	Ion Selective Electrode	2
	Oil and Grease	<1.0	mg/L	Liquid-Liquid, Partition - Gravimetric	5
	Phosphate as Phosphorus (Total, Reactive)	0.11	mg/L	Stannous Chloride	4 ᵇ
	Sulfate (SO_4^{2-})	219	mg/L	Turbidimetric	550 ᵃ
	Surfactants (MBAS)	< 0.10	mg/L	Anionic Surfactants as MBAS	15
	Temperature	31	°C	Laboratory and Field	3 ʰ
	Thermotolerant (Fecal) Coliform	23	MPN/100mL	Multiple Tube Fermentation Technique - Fecal Coliform Procedure	400 ᵇ
	Total Suspended Solids (TSS)	8	mg/L	Gravimetric, dried at 103-105 °C	100
	pH	7.5	-	Electrometric	6.0-9.5

D. March 2024 testing results for copper

CERTIFICATE OF ANALYSIS

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Date of Issue : 3/19/2024
BATCH : B-24231A
Date Received: 3/6/2024
Date Sampled: 3/6/2024
Date Analyzed: 3/6-14/2024

RESULTS OF ANALYSIS

Sample Descriptions	Parameters	Results	Units	Methods	DAO 2016-08 Effluent Standards, Class C
Wastewater Effluent					
STP Outfall	Ammonia as NH_3-N	3.28	mg/L	Ammonia - Selective Electrode	4 [a]
11:14AM	Copper (Cu)	0.634	mg/L	ICP-OES	1 [a]
	Nitrate as NO_3-N *	1.01	mg/L	Colorimetric, Brucine	14
	Zinc (Zn)	0.057	mg/L	ICP-OES	4

E. Cost per cubic meter of water produced in WRS.

OPERATION AND MAINTENANCE COST

REV #	DATE	PREPARED BY
00	29-Aug-2023	M. Aguila

Company Name : Onsemi
Project Title : 150 gpm MMF-ACF-RO system
Document No. : 70-01-OSP230447-1-00

Prepared by :
Maidel Aguila
Process Team Leader

Approved by:
Lawrence James
Technical Director

ELECTRICITY CONSUMPTION

Based on Php 7.6 /kW-hr and 24-7 operation, 365 days

Equipment	Qty	Motor Power		Service Hours	Frequency of Operation	Consumption (kW-hr)	Annual Cost
Feed Pump	1	11.00	kW	24	daily	264.00	727,518.00
First Pass RO High Pressure Pump	1	22.00	kW	24	daily	528.00	1,455,036.00
Antiscalant Dosing Pump	1	0.28	kW	24	daily	6.72	18,518.64
HCl Dosing Pump	1	0.28	kW	24	daily	6.72	18,518.64
SBS Dosing Pump	1	0.28	kW	24	daily	6.72	18,518.64
Antiscalant Dosing Pump	1	0.28	kW	24	daily	6.72	18,518.64
Chlorine Dosing Pump	1	0.28	kW	24	daily	6.72	18,518.64
TOTAL							**Php 2,275,147.20**

CONSUMABLES (c/o ONSEMI)

MATERIALS	No. of Units	Quantity/Amount Used		Freq. of Use/ Replacement	Quantity used per Year		Unit Price	Annual Cost
Chlorine Dosing								
Chlorine	1	40.00	cby	monthly	480	cby	525.00	252,000.00
HCl Dosing								
Hydrochloric acid	1	336.00	cby	monthly	4032	cby	516.00	2,080,512.00
Sodium Hydroxide								
48% sodium Hydroxide	1	168.00	cby	monthly	2016	cby	980.00	1,975,680.00
TOTAL, (VAT EX)								**4,308,192.00**

RENTAL COST (MANPOWER, EQUIPMENT RENTAL, CONSUMMABLES by MTI, OPERATIONS AND MAINTENANCE)

MATERIALS	No. of Units	Quantity/Amount Used		Freq. of Use	Quantity used per Year		Unit Price	Annual Cost
Rental Cost								
Rental Cost	1	1.00	lot	monthly	12	months	3,380,000.00	40,560,000.00
TOTAL, (VAT EX)								**40,560,000.00**

† Membrane life is expected to be 3-5 years assuming good pretreatment.

TOTAL ANNUAL MAINTENANCE COST (VAT Ex)	***Php 47,143,339.20***
Annual Product Water Consumption (m^3)	***298,366 cubic meter***
Cost of Product Water/m3	***Php 158.01 per cubic meter***

NOTES: Computations are based on 24 hours, 7 days a week operation.
Prices are EXCLUSIVE of Tax
Prices are subject to change without prior notice after Validity Period of 30 days.

F. 2022 onsemi Sustainability Report