REUSING OF REVERSE OSMOSIS (RO) REJECT WATER THROUGH CREATION OF WATER HARVESTING SYSTEM TO CONSERVE WATER AND TO PRESERVE ENVIRONMENT FOR FUTURE GENERATION

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ABSTRACT

Water conservation refers to reducing the usage of water and recycling of wastewater for different purposes such as irrigation, laundry and sanitation. As water scarcity increases, large establishments such as manufacturing company should be focused on how to conserve water in most economical way.

This project emphasizes how to reuse the reject water from Reverse Osmosis (RO) system. By collecting it thru the use of PVC pipes, conveying and storing it in a tank, and distributing it by the use of pump, reusing reject water as an alternative water supply, is possible.

Prior to the execution of RO reject water harvesting system, water quality analysis was conducted before using it for flushing urinals and water closets, building general cleaning and cooling tower make-up water. This project proved that reusing this water will help the company to improve and reduce the water consumption.

1. 0 INTRODUCTION

Water is one of the essential requirements in life. It is used for a variety of purposes, including drinking, food preparation, irrigation, domestic use and manufacturing. In manufacturing and other industries, water is used during the production process for either creating their products or cooling the equipment. Other production processes require demineralized or deionized water which is a product produced by a Reverse Osmosis (RO) System.

Reverse Osmosis System works by using a high-pressure pump to increase the pressure on the salt side of the RO and force the water across the semi-permeable RO membrane, leaving almost all of dissolved salts behind in the reject stream (See Fig. 1 and 2).

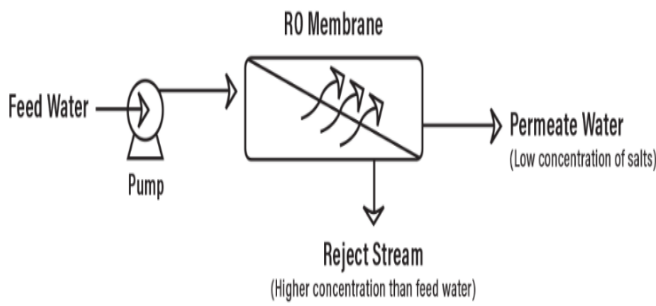

Figure 1. Reverse Osmosis System Diagram

Figure 2 - Reverse Osmosis System

RO reject or the reject stream is fit for many reuse purposes. Typical reuse opportunities at most sites are toilet flushing, garden watering, cooling tower water and for general cleaning. Reusing this water will give a beneficial impact in terms of water consumption most especially in an establishment that consumes large amount of water. Reducing water usage by reusing the reject stream will also minimize the effects of drought and water shortages, helps to preserve our environment and keep our sources pure and safe for generations to come.

In order for this to be possible, a provision of RO reject water harvesting system is necessary.

1.1 Osmosis

Osmosis is the spontaneous passage or diffusion of water or other solvents through a semipermeable membrane. It is a process where a weaker saline solution tends to migrate to a strong saline solution. Osmosis naturally moves solvents across a membrane from the side of a higher concentration to the side where the concentration is lower. Examples of osmosis are when plant roots absorb water from the soil and when our kidneys absorb water from our blood.

In the diagram below (See Fig. 3), the concentration of sugar is initially higher on the right side of the membrane. Therefore, water moves by osmosis to the right-hand side to equalize the concentrations.

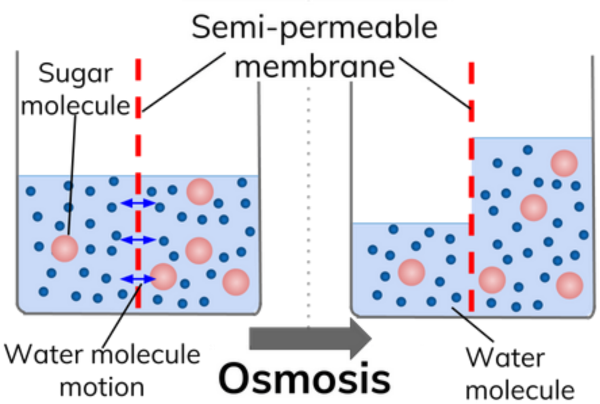

Figure 3. Osmosis Diagram

1.2 Reverse Osmosis

The process of reverse osmosis is used in the desalination and purifying of water. It is osmosis in the other direction, as the name implies. Water is pushed through a semi-permeable membrane against the concentration gradient by applying a pressure larger than the natural osmotic pressure (See Fig.4). As a result, water molecules migrate from a low water potential to a higher water potential across a reverse osmosis membrane. Dissolved salts, organics, microorganisms, and pyrogens, for example, will not flow through the barrier. As a result, reverse osmosis makes it easier to filter water in water purification procedures.

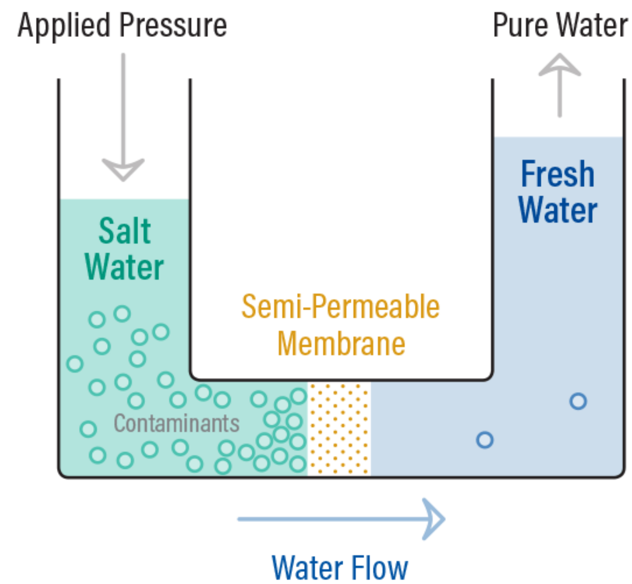

Figure 4. Reverse Osmosis Diagram

1.3 Reverse Osmosis Membrane

A reverse osmosis membrane is a semi-permeable membrane that allows the passage of water molecules but not the majority of dissolved salts, organics, bacteria and pyrogens (See Fig.5). Pushing the water through the reverse osmosis membrane by applying pressure that is greater than the naturally occurring osmotic pressure in order to desalinate (demineralize or deionize) water in the process, allowing pure water through while holding back a majority of contaminants.

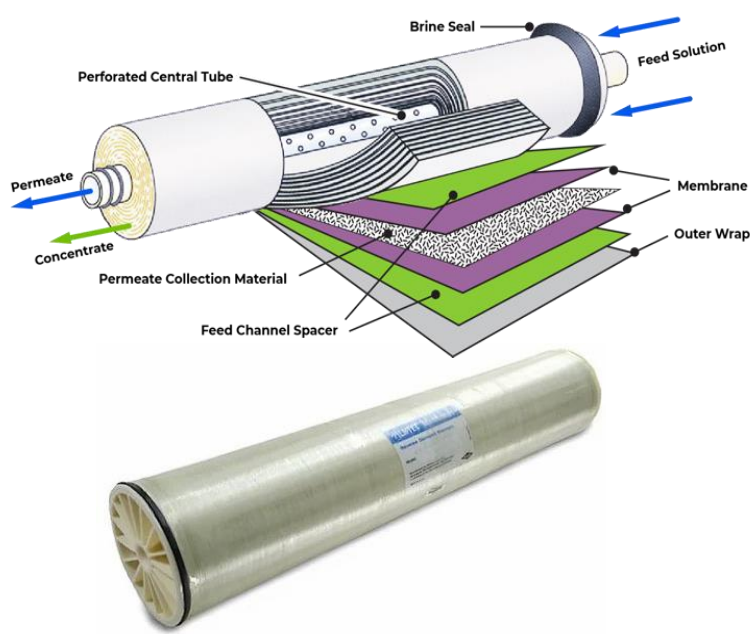

Figure 5. Reverse Osmosis Membrane

1.4 Water Pump

A water pump is a machine used to increase the pressure of water in order to move it from one point to another (See Fig.6). In reverse osmosis system, pump works by forcing the water through a semi-permeable membrane at a pressure high enough to overcome the natural osmotic pressure.

Figure 6. Vertical Multi-Stage Water Pump

2. 0 REVIEW OF RELATED WORK

According to John W.M. Agar, Department of Nephrology, University Hospital Geelong, Geelong, Victoria, Australia, in his study entitled, Reusing and Recycling Dialysis Reverse Osmosis System Reject,

> "As good global citizens, it is our responsibility to minimize waste wherever we can, and, while clearly the conservation and reuse of RO system reject water will contribute but a drop in the ocean of water that is currently thoughtlessly wasted, every drop helps. As the service providers of dialysis, we have ignored the environmental costs of dialysis for too long. We should be seeking ways to make a greater contribution to the health of the global environment and begin to pay back some of the capital we have squandered."

The author explained the following procedures on how reusing of RO reject water is possible:

> "In our eight-station hospital in-center setting, two 36,000-liter holding tanks (donated by local industry) were installed on an eighth-floor rooftop, from where, under gravity feed, RO system reject water was piped to the hospital centralized sterilizing department to provide steam for its autoclave systems.
>
> In addition, inflow plumbing connections were installed to selected toilets for waste flushing and to adjacent janitor stations for use in floor cleaning. Any remaining water is directed to landscaping. A full return on this investment was realized in about 30 months, with subsequent hospital water expenses decreasing significantly thereafter.
>
> At our 16-station suburban satellite center, two further industry-donated tanks store RO system reject water for free collection by schools, playing fields, and city parks and gardens. In the home setting, tanking and piping for domestic laundry, window cleaning, horticultural, or agricultural purposes (for instance, animal watering) has become a routine home HD package that adds a one-time approximately Au$3000 to home installation costs. Again, while RO system reject water is potable standard water and is safe to drink—it is similar to mineral water—local testing may be needed to persuade and confirm potability to local authorities. RO system reject water can also be recycled back through a closed loop system for re-presentation to the RO system, either with or without ongoing mains water mixing and/or dilution. RO system reject water recycling is described in more detail elsewhere. However, as recycling will inevitably cause the conductivity at the RO membranes to slowly but progressively rise, a conductivity probe should be located within the RO system to detect whether the conductivity is approaching or exceeding membrane-safe limits. In case this should occur, the system can simply be engineered to either manually or automatically revert to mains feed for the remainder of the treatment. This system has been successfully and continuously operated without incident in a number of home dialysis installations since 2007, though regular bacteriological testing is advised. However, in the experience of this group, the need to revert to mains water feed mid-treatment has been rare."

3.0 METHODOLOGY

3.1 Measurement of RO Reject Water Volume

It is essential to know the volume of RO reject water being generated from the RO system operating in the plant. This is to measure how much opportunity is being wasted from this system.

Based on the facility daily roving water monitoring check sheet, below are the following reject rate from year 2021 – 2022 (See Table 1).

Table 1. Volume of RO Reject Water

LOCATION	CONSUMPTION (m3)		AVE. YEARLY (m3)	AVE. DAILY (m3)
	2021	2022		
RO SYSTEM 1	1,790	931	1,360.43	3.73
RO SYSTEM 2	6,147	5,599	5,873.29	16.09
TOTAL				**19.82**

The total average daily discharge rate from the table above will be used as the volume capacity of harvesting system per day.

3.2 Identification of RO Reject Reuse Opportunities

There are many potential uses for RO reject water located inside the site. The designer only limits the application of reuse water for toilet flushing, garden watering, janitorial use like floor mopping and clothe laundry, cooling tower and for general cleaning.

Selected point of use for the reject water was based on the available volume of reject water, location of harvesting system and the water demand per point of use.

Below are the selected locations that was also based on the facility daily roving water monitoring check sheet (See Table 2).

Table 2. Water Consumption of Selected Location

LOCATION	CONSUMPTION (m3)		AVE. YEARLY (m3)	AVE. DAILY (m3)
	2021	2022		
COOLING TOWER 2	212.00	212.00	212.00	0.59
COOLING TOWER 3	3,254.30	1,131.30	2,192.80	6.09
Legend (Janitorial) Quarter - Wash Basin Area	109.07	209.16	159.11	0.44
Building 1 Male Locker Room Comfort Room	513.61	571.32	542.46	1.51
Building 1 Female Locker Room Comfort Room	2,448.84	2,692.92	2,570.88	7.14
TOTAL				**15.77**

Comparing the total demand on the above table to the total reject water produced from the system, it is noticeable that the proposed harvesting system can satisfy the volume required per location.

3.3 RO Reject Water Quality Testing

After the confirmation that the RO reject water matched the demand from the selected location, it is necessary to confirm that the RO reject water is fit-for-purpose.

To confirm the quality of RO reject water, the designer conducted physical and chemical water analysis and compared it to the existing quality of water being used on the selected location (See Table 3).

Table 3. Physicochemical Water Analysis Comparison Table

Parameter	Result		Reference	Remarks
	Raw Water	RO Discharge		
Color	10 @ pH 6.9	2 @ pH 8.0	10	Passed
Turbidity	3.6	2.3	5	Passed
TDS	424	388	600	Passed
pH (On-site)	6.9 @ 30.3°C	8.5 @ 31.3 °C	6.5 - 8.5	Passed
Lead	Less than 0.008	Less than 0.005	0.01	Passed
Nitrate	Less than 0.10	Less than 0.15	50	Passed
Arsenic	0.01	0.008	0.01	Passed
Cadmium	Less than 0.003	Less than 0.003	0.003	Passed
Iron	0.4	0.03	1	Passed
Manganese	0.06	Less than 0.02	0.4	Passed
Residual Chlorine (On-site)	0.04	0.02	Chlorine Test Kit	Passed

Comparing the result of raw water and RO reject water for the physicochemical analysis, it is noticeable that they both passed the given parameters as reflected on the above table.

3.4 RO Reject Water Harvesting Design

Since the quality of RO reject water was already verified, the next step is to know how the RO reject water will get to the selected location.

From the RO membrane reject line, water will be transferred to backwash tank that is used during the backwash process of RO system (See Diagram 1). Overflow from backwash tank will be transferred to proposed Reject Water Storage Tank or the RO Harvesting Tank (HT) via gravity, since backwash tank elevation is higher than HT. Considering that the HT is located on the ground, conveying it to selected point of use via gravity is not possible. Installation of water pump is necessary.

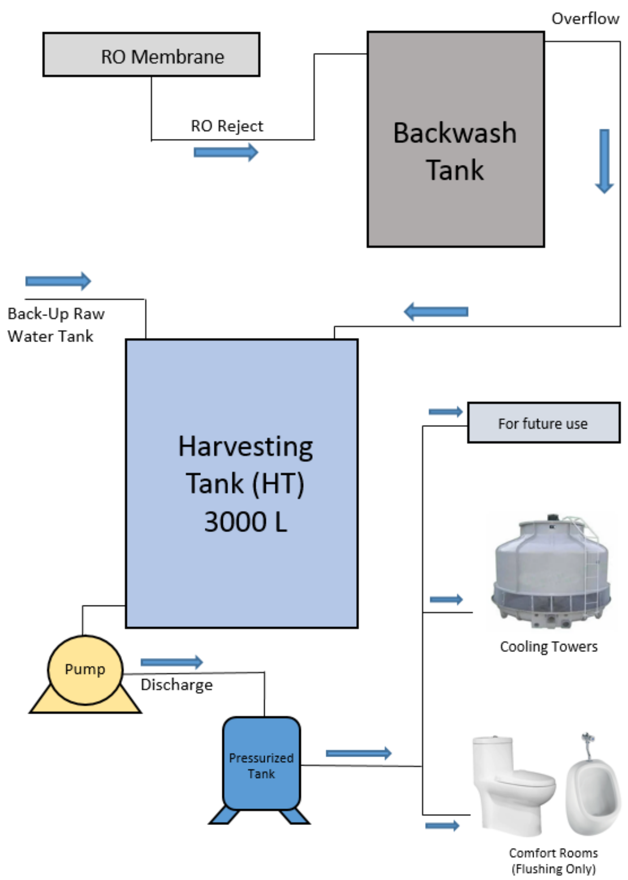

Diagram 1. RO Harvesting System Diagram

From HT, water will be distributed to selected point of use via pressure created by the pump. The designer also considers the size of pump based on the water demand, required pressure, size and length of pipe including losses and elevation. Pump sizing will be discussed separately on the next topic. To maintain the pressure requirement, the designer included pressure tank with cut-in and cut-off pressure switch. From the pump, created water pressure will be distributed to the following location and purposes:

- **Female and Male Locker Room Comfort Rooms** – Water will be used for flushing water closets and urinals including the general cleaning of CR.
- **Janitorial Wash Basin** – intended for the laundry of clothes used in general cleaning, washing of mops for floor mopping and other janitorial activities.
- **Cooling Tower** – supply of make-up water line and will be used during preventive maintenance activities.

To prevent water supply interruption on the time that the RO Membrane is not discharging reject water, the designer considered the installation of raw water back-up line that will supply raw water on HT when it reaches the set water level (See Diagram 2).

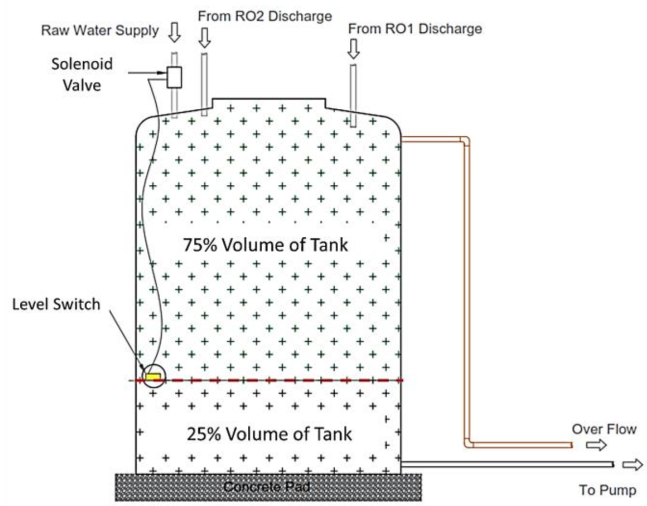

Diagram 2. RO Harvesting Tank Details

Raw water will be supplied on the HT when the tank reaches below 25% of tank capacity and will stop supplying at exactly 25%. This additional part will prevent the tank of being drained and to avoid damage on pump operation.

3.5 Pump Sizing

In sizing the pump, the following requirement must be considered:

- Volume Flow Rate of Pump
- Pump Head
  - Pressure Head
  - Velocity Head
  - Elevation Head
  - Friction Losses

For volume flow rate, aside from the volume required of the selected location, the designer also considered the volume of future use and other factors (losses, leaks, etc.) which is equivalent to additional 150%. But this consideration will also require the expansion of harvesting tank volume capacity.

Volume Flow Rate = 16m3/day = 0.67m3/hr
Volume Flow Rate = 0.67 + 150% = **1.7m3/hr**

After the identification of volume flow rate, pump head must be considered as well. Below is the list of computed head based on the proposed installation details.

Table 4. Computed Pressure Head

Pump Heads	Meter(m)
Pressure Head	35
Velocity Head	0.04
Elevation Head	5.16
Friction Losses	18
Total Pump Head	**58.2**

Based on the computed pump requirement, selection of pump size is possible.

3.6 RO Water Harvesting System Installation Details

On this design, there are two RO reject water lines that will be harvested, one is from RO system no. 1, RO system intended for drinking water, and the RO system no. 2, RO system intended for production processes. Below is the diagram (See Diagram 3 and Figure 7) on how water will be collected a discharge to selected location.

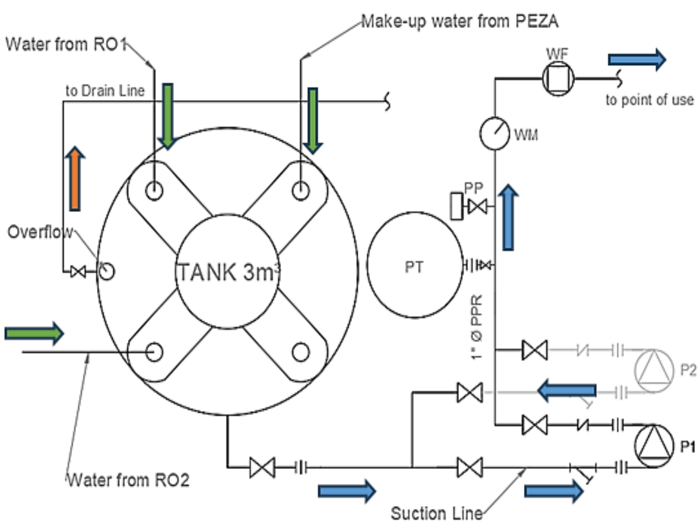

Diagram 2. RO Harvesting Pump and Tank Diagram

Figure 7. RO Reject Water Harvesting System

3.6.1 RO Water Harvesting Pipe

For RO 1, pressurized reject water from RO membrane will be transferred directly to 2" PVC pipe and convey it to HT. For RO 2, overflow from RO 2 backwash tank will be transferred also to 2" PVC pipe and deliver it to HT via gravity (See Figure 8 and 9).

Figure 8. RO 1 Harvesting Pipe

Figure 9. RO 2 Harvesting Pipe

3.6.2 Harvesting Tank Details

Harvesting tank is the tank were the reject water from RO 1 and 2 will be stored. For economical purposes and to reduce investment cost, available tank from the dismantled RO system on the other site was used (See Figure 10). As discussed on topic 3.4, the designer included raw water line to prevent the draining of tank and to avoid damage on pump operation (See Diagram 2).

Figure 10. RO Reject Water Harvesting Tank

3.6.3 Pump, Pressurized Tank, Pressure Switch, Water Filter and Water Meter Details

Since pump specifications were already computed on topic 3.5, the designer already selected available pump which is near on the computed pump specs (See Figure 11).

Computed Specification:

- Volume Flow Rate: 1.7m3/hr
- Total Head: 58.2 m

Available Pump Based on Computed Specs:

- **Brand and Type: ''ESPA''** Vertical-In-Line Multi-Stage Centrifugal Pump
- **Model:** Multi 25-4, 4 stages, 1-1/4'' suction and discharge ports, rated to deliver
- **Pump Capacity:** 2m3/hr against 60m TDH, with mechanical seal, Stainless steel casing, impeller and diffusers; coupled to a 1.5 HP Electric Motor, 3500 rpm, IP55, 220Volts, 1Phase, 60Hz

Figure 11. RO Reject Water Distribution Pump

To maintain pressure even the pump is not running and to provide reserve water supply during times of high demand, a 100L pressurized tank was installed (See Figure 12). Pressure switch was also included so that the pump will start and stop that will prolong the life of pump. To ensure the cleanliness of supply water, the designer included a 5.0 micron in-line water filter on the discharge side of pump.

Figure 12. Pressurized Tank and In-line Water Filter

To measure the actual result of this RO harvesting system and to know how much water is being conserved, a water meter was installed on the discharge side (See Figure 13).

Figure 13. Discharge Water Meter

3.7 Pump Controls

For the pump controls, a 16”x16”x8” control box was installed (See Figure 14) indicating the below components:

- Indicator Lights
  - For Solenoid – it will light-up once the solenoid valve for raw water supply is ON
  - Pump Motor – it will light-up during pump operation
  - Power – indicates power panel energization
  - Fault – it will light-up once there is a fault encountered
  - Start and stop – it tells whether the pump has started or stopped
- Selector Switch – set the function of the whole system (AUTO, OFF or MANUAL)

Figure 14. RO Harvesting System Control Panel

4.0 RESULTS AND DISCUSSION

From the data acquired on the installed water meter located at the discharge side of pump after the implementation date (June 2023), it is noticeable that the system already generated savings (See Table 5).

Table 4. Volume of Reused Reject Water

Saving for FY 2023	
Month	Savings (m3)
June	428.23
July	447.33
Aug	-

Comparison of previous water consumption before and after the implementation date was reflected on the below chart (See Chart 1).

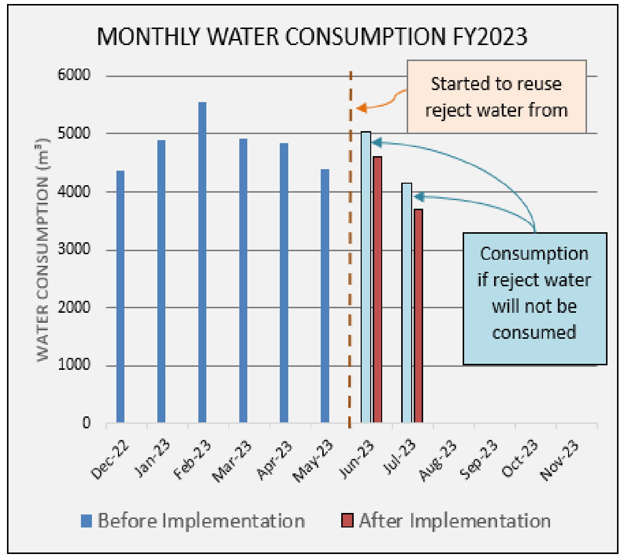

Chart 1. Monthly Water Consumption for FY 2023

Based on the above table regarding the volume of reused reject water from RO system, total water saved is **875.56** cubic meter or raw water which is equivalent to **17,160.98** pesos as of July 2023.

Total water expected to be saved for 1 year will be **5,253.36** cubic meter which is equivalent to two standard Olympic sized swimming pool and with a total water consumption cost of **102,965.86** pesos.

Total project cost for this system is 142,017.96 pesos. With this, return of investment (ROI) can be calculated.

ROI = 142,017.96/102,965.86 = 1.38 Years or
1 Year and 4 months

5.0 CONCLUSION

This project concluded that reject water can be reused to promote water conservation with encouraging results. Reusing of RO reject water as an alternative water supply for flushing urinals and water closets, janitorial use, cooling tower make-up water and for building general cleaning, was effective and can help the company to improve and reduce the water consumption. In addition, due to new water pump supplying the selected location, pressure was improved and no major concern was encountered.

Since the distribution of raw water supply requires energy for the pump or booster pump operation, reduction of water usage will also save energy that will absolutely help on the reduction of carbon footprint.

6.0 RECOMMENDATIONS

To collect the water from RO reject line 100%, it is recommended to use a large size harvesting tank so that there is a small chance of disposing again the RO reject water to drain after collecting it. It is also recommended to conduct again another water testing considering other water parameters (Hardness, Silica, Alkalinity, Bicarbonate, Sulphate, Calcium, Magnesium, TSS, etc.) so that considering other application that consume large amount of water like washing of dishes and food preparation in the canteen area will be considered.

Another way also that can be considered to help to reduce water consumption is the use of rain water harvesting system. But further study is required most especially with the quality of this water.

7.0 ACKNOWLEDGMENT

This technical paper would not be made possible without the help of the following:

To P. IMES Corp for the generous support of approving the proposal including the budget and for the opportunity to present this paper in the 32nd ASEMEP National Technical Symposium.

To Mr. Tetsuya Matsusaki and Ma'am Florafe Bantayan for getting the proposal approved.

To Sir Jonathan Custodio for helping the author in getting the proposal approved.

To Sir Jazz Dayroll Basubas for the guidance, suggestions, and support to the author while doing this project.

To the Facility Technicians and Building Maintenance for helping the author in the installation works of whole project including the data gathering.

To Dianne Mae B. Erni for being responsible in proofreading the whole paper.

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