INDUSTRIAL ATTACHMENT REPORT

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Acknowledgement

First and foremost, we would like to extend our appreciation to the management of Namwater and UNAM for allowing our team to do Industrial Internship at the Grunau Desalination Plant. We sincerely are thankful to all the following individuals who in one way or another were involved and made our placement more fruitful. We would like to appreciate Ms Victoria Sem (HR Development Practitioner) who was the key organizer and coordinator for our placement with Namwater and Ms Rebecca Kahuva (HR) for the induction. We acknowledge with appreciation Mr. John Sirunda, Ms Angela Nakale, Mr. James Heita (Research and Development Department Namwater) as well as Dr Fillemon Nangolo(UNAM) for their research and academic guidance and support.

Furthermore, big thank you to Ms Pauline Shetukana for welcoming us at Grunau Desalination plant and for her continuous support and guidance. Mr. Maketo (CRO Grunau Settlement) and Ms Melisa(Namgate) for welcoming us to Grunau and their effort to organize our accommodation. We appreciate the great team work of all the colleagues we were working with on day to day basis starting with Ms Ester Petrus for her extraordinary leadership, motivation and constant support. Mr. Jason Lungambo for sharing his expertise and commitment. Mr. Nestor Shikatu and Ms Tresia Haihambo(NEC) for their constant training on the plant operations. Mr. Henry and Beukes for sharing techniques on boreholes rehabilitation and solar system installation.

We would also extend our appreciation to our families for the support and motivations and it is because all the individuals the team finds the courage to keep striving and working with dedication on the research work related to Brackish water desalination technologies.

Finally, we acknowledge the effort and dedication of each and every team member (Sam Shaanika, Immanuel Shahonya, Tomas Nkandi and Andile Motsa).

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Abstract

The engineering curriculum has integrated the Industrial attachment/internship for students/staff to be placed in Industries for the minimum duration of 6 -18 weeks. This work-integrated learning exercise is compulsory for students before they graduate. The industrial attachment is meant to prepare students to be job ready and help increase graduate employability as well as provide golden opportunities to students/staff to align their design and research projects to real practical industrial needs (applied research). A team of 3 students and 1 academic staff was placed for industrial attachment/internship at the Grunau Desalination Plant as from the 07 June -16 July 2021. The team with initial interest in brackish water Desalination technologies using hybrid renewable energy (solar and wind) have been exposed to the Pilot plant of Grunau operations, the Borehole rehabilitation/ maintenance, solar power system installations, data collections. In additions, the team was involved on the day to day activities and duties of the plant Grunau and other locations example sampling Ai-Ais, Noordoewer, Aussenkehr, Warmbad.

More data will be required specifically on the RO operating parameters as well as on renewable energies to help with research work and provide appropriate conclusions

INTRODUCTION

Current Organogram

During the industrial attachment duration, the team was reporting to the below organogram structure of the Grunau Desalination plant as indicated in figure1 below.

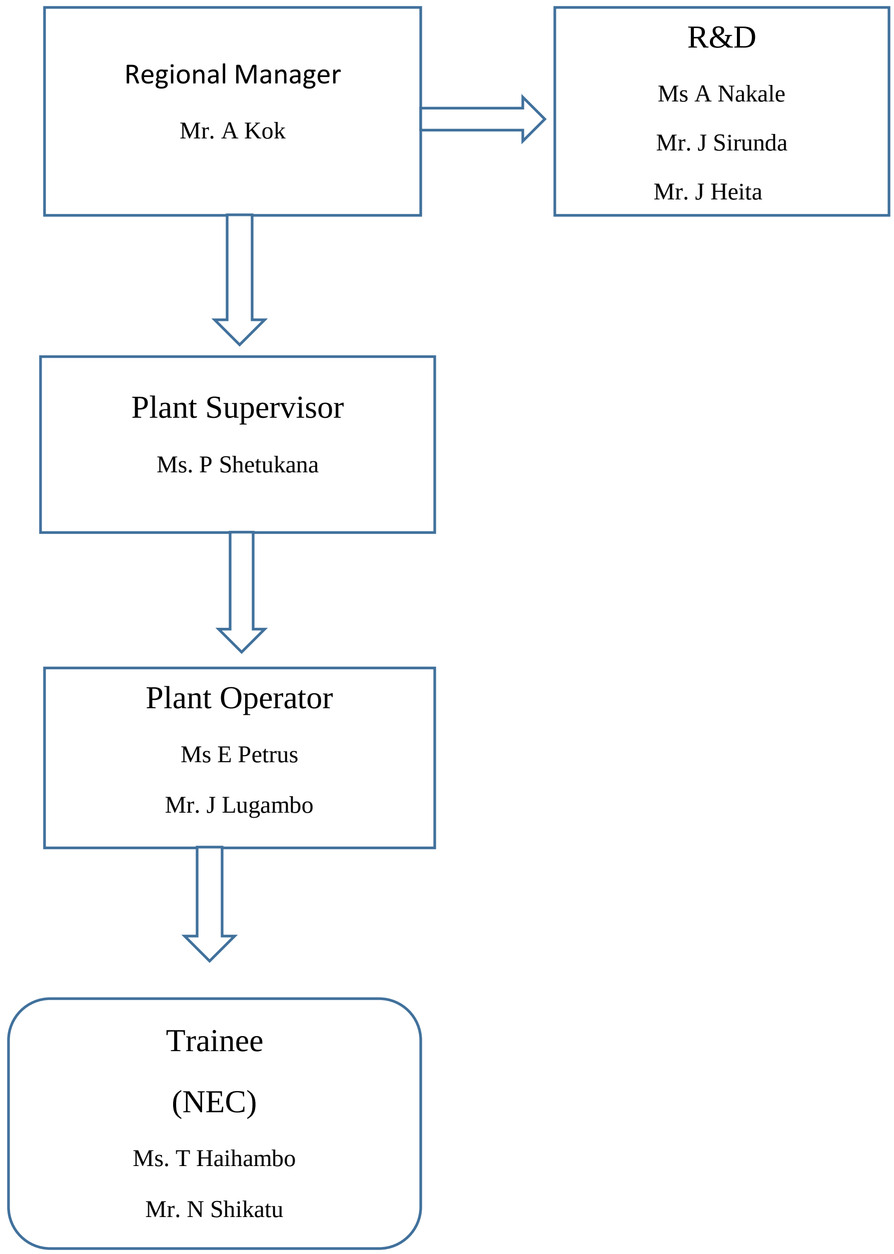


Figure 1. Grunau Plant organogram

Plant Location

Grunau is a settlement situated in Karas region south of Namibia approximately 1368 Km from Ongwediva when traveling by car on the B1 tar road as indicated in Figure 2 below. The Grunau water supply scheme consists of 6 boreholes with a recommended total abstraction of 30.5 m3/day as shown in table 1. The projected water demand of Grunau is 36 m3/day and therefore Namwater has plans in place to incorporation three more additional existing boreholes which are to be installed and be connected to the bulk water supply system. With the additional of the boreholes' the abstraction capacity is expected to increase up to 47.3 m3/day. The plant design capacity is 46.8 m3/day with RO treating approximately 28.9 m3/day(permeate) and making a final drinking water (Permeate + filtered water which is also referred as blended water) of 36 m3/day. The plant is located on the GPs coordinate 27°42′54.74″S and 18°22′29.02″E

The Grunau RO Desalination Plant powered by the hybrid renewable energy which was constructed by Namibian Engineering Corporation (NEC) power and pumps and was officially inaugurated on the 23rd October 2020.

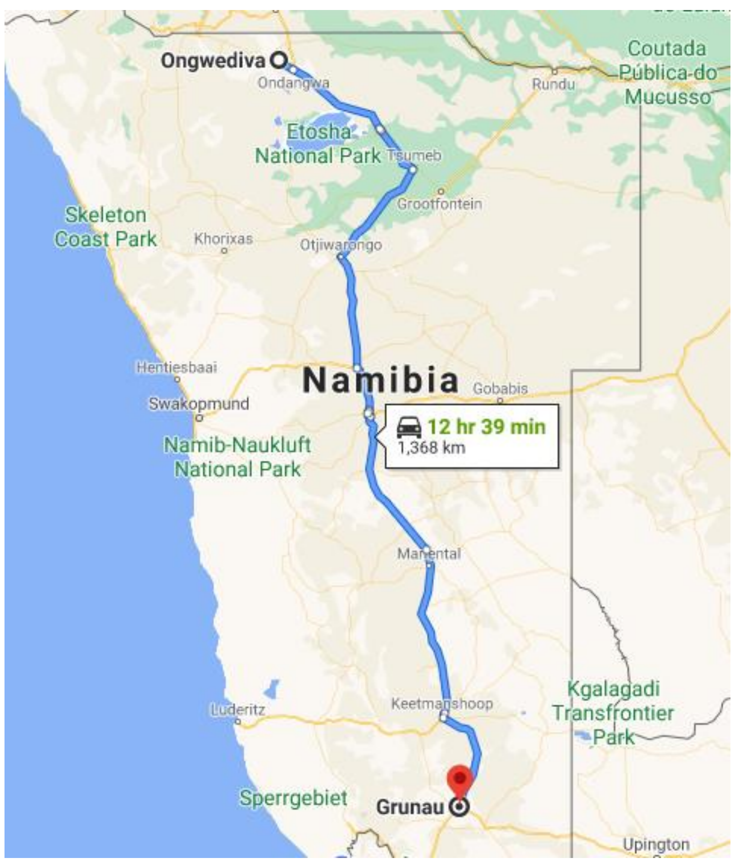


Figure 2. Grunau Plant Location

Table 1 boreholes site coordinates

Borehole Number	GPS Coordinates	
WW23404	27°39′11.94″S	18°20′58.42″E
WW23405	27°39′20.83″S	18°20′59.42″E
WW23406	27°43′24.72″S	18°22′29.21″E
WW23407	27°42′47.91″S	18°23′20.05″E
WW33890	27°42′44.33″S	18°22′28.38″E
WW33891	27°42′43.02″S	18°22′34.83″E

WATER ABSTRACTION

Boreholes

The team was involved in the installation of the pump, solar panels and pipe fittings during the rehabilitation of the borehole which was recently added to the bulk system water supply as shown in figure 3 Below. The six borehole each has a pump house station and structure on top of which solar panel (PV module) are installed. The pumps can be solar or petrol/diesel generator powered. Each borehole pump station is installed with flow meter, production water meter (water meter reader), pressure gauge and Timer (hour meter) from which the abstraction data are obtained. From time to time, the team visit the boreholes to measure the rest water level (in the mornings/evenings when the pump is not in operation) and pump water levels (in the afternoons when the pump is in operation) to monitor the abstraction levels using depth meter (sound/light probe sensor). Appendix Boreholes data

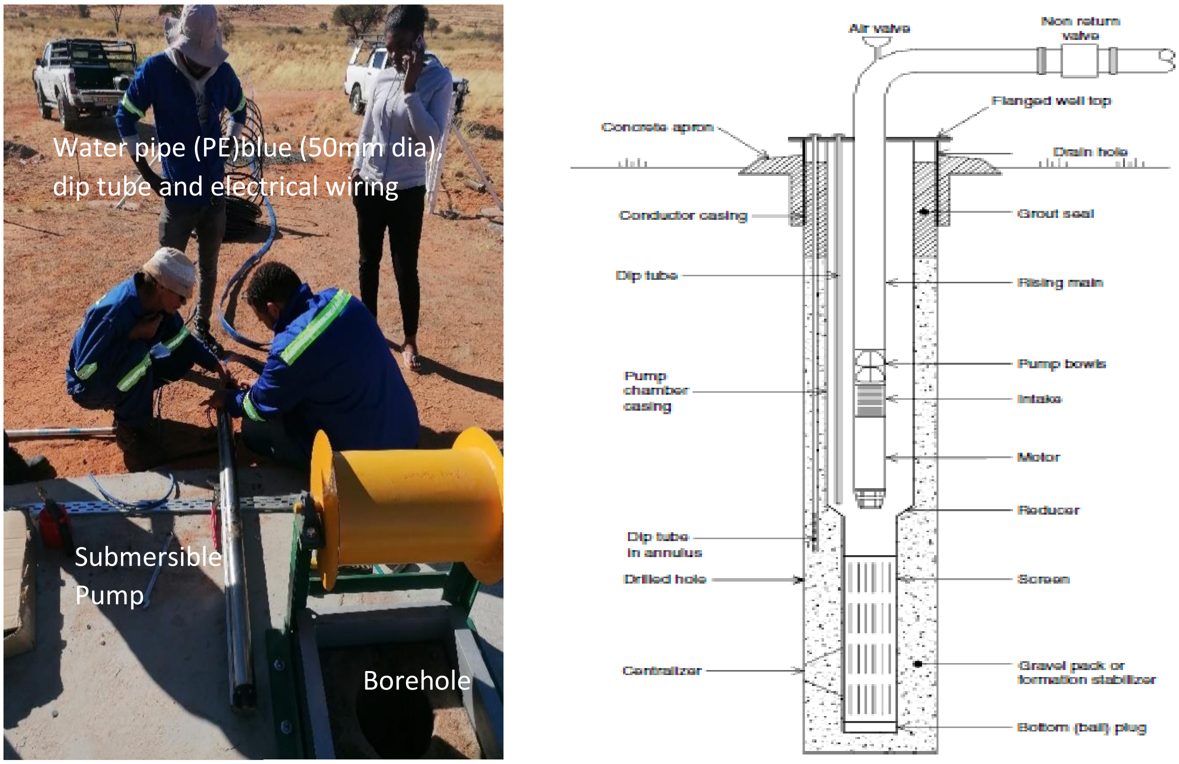


Figure 3. Components of drilled borehole

Table 2 boreholes recommended abstraction

Borehole Number	**Recommended abstraction**				
	m^3/h	m^3/day	$m^3/month$	$m^3/annum$	h/day
WW23404	1.3	6.5	180	2160	5
WW23405	1.2	6.0	180	2160	5
WW23406	1.2	6.0	180	2160	5
WW23407	1.2	6.0	180	2160	5
WW33890	1.0	4.0	120	1440	4
WW33891	1.0	2.0	60	720	2

DESALINATION PROCESSES

The Plant is powered by solar (64 panel 300W each) and wind energy (Wind turbine 800W), with a design energy consumption of 0.83 kWh/m3. It consists of three main sections namely: Pre-treatment, Reverse Osmosis(RO) and Post treatment. The Pre-treatment processes includes coagulation, Cartridge filter(5micron), two pressure sand filters, chemical conditioning which includes the dosing of anti-scalant, sodium metabisulphate and PH correction as required. The RO section incorporates the feed tank, pressure feed pumps, CIP tank, membrane vessels with eight elements (Hydranautics ESPA2-4040). Brine and blending recycling is integrated during operation. The post treatment section includes chlorination and PH adjustment (when required)

The sources of raw water are the 6 boreholes which feed into the 100 m3 concrete reservoir which is equipped with a level ultrasonic sensor to monitor the starting and stopping of the feed water pumps and therefore them from sucking in air. This raw water is referred as Brackish water which contains contaminants and high level of fluoride (2.4 mg/l) and nitrate (33mg/l). There are online instrumentations for data capturing and reading for raw water, Filtered water, RO feed, Permeate, Brine, blended and final (Product water) to measure the various parameters such as flow rate, turbidity, electrical conductivity, PH, temperature and pressure.

Sand Filtration

The objective is to remove suspended solids from raw water and the filter media used in the plant are the dual media filter bed with the bottom layer of 700 mm of Silica(Sand) of effective size of 0.6 mm and uniformity coefficient less than 1.4 and the top layer of 300 mm of Anthracite of effective size of 0.9 mm and uniformity coefficient of less than 1.6 mm.

Chemical Dosing

The Grunau Desalination plant has incorporated chemical dosing which are meant to treat water to help with coagulation and flocculation, PH correction, Anti-scalant and Anti-fouling. The chemicals are added in to water by using of dosing pumps which are set to the required dosing rate as pre-determined. The following are the chemicals used:

1. Ferric Chloride ($FeCl_3$) a flocculants added prior to flocculation chambers. Rapid dispersion and mixing of the coagulant is extremely and therefore this to be achieved there is an incorporated an in-line static mixer downstream which is used to guarantee acid is properly mixed. A static mixer is installed close to the pumping station.

Dosing rate 422 ml/h

Mining 18 litter of permeate, 2 litter of ferric solution

2. Sodium Hydroxide(NaOH) referred to as Caustic is used to increase the PH levels

   Dosing rate 1.00 l/h.

   Mixing 200 ml of caustic + 18 litter of permeate

3. Hydrochloric Acid(HCI) is use to lower/ decrease the PH levels.

   Dosing rate

4. Sodium Hexametaphosphate (SHMP) is used as anti-scalant to suppress the precipitation of salts on the RO membrane.

   650 ml/h. dosing rate

   Mixing ration (0.16 kg + 20 litter of permeate)

5. Sodium metabisulfite (SMBS) also known as Biocide used to avoid biofouling on the RO membranes as for the removal of free chlorine.

   Dosing rate 656 ml/h.

   Mixing 0.18 kg + 20 litter of permeate

OPERATION PROCESSES

Raw water

- Incoming flow of raw water from the borehole, is tested for turbidity, conductivity, pH and the flow rate of the pumps.

Pretreatment Process

- Flocculation chamber 1, chamber 2 and flocculation hopper where settlement of big/solid particles take place. Ferric chloride is added to remove impurities from raw water. Ferric chloride enhances the coagulation and flotation process and filtration to remove particles matter from raw water.

- Backwash tank overflow to the RO feed tank, backwash is done when the turbidity goes high up to + 0.12 NTU for filtered water.

RO feed tank

- Water flow through RO pumps where chemicals; anti-scalant (sodium Hexametaphosphate), caustic (pH correction), sodium metabisulphate / SMBS (Remove chlorination).
- The treated water flows/ run through cartridge filters and then further to the RO membranes.
- The two installed membranes; stage 1 and stage 2 connected in series. Treated water is fed through to 1st stage membrane and flows to the 2nd stage before membrane filtration takes place. Permeate from 1st stage is same quality as that from 2nd stage.

Plant Process Flow Chart

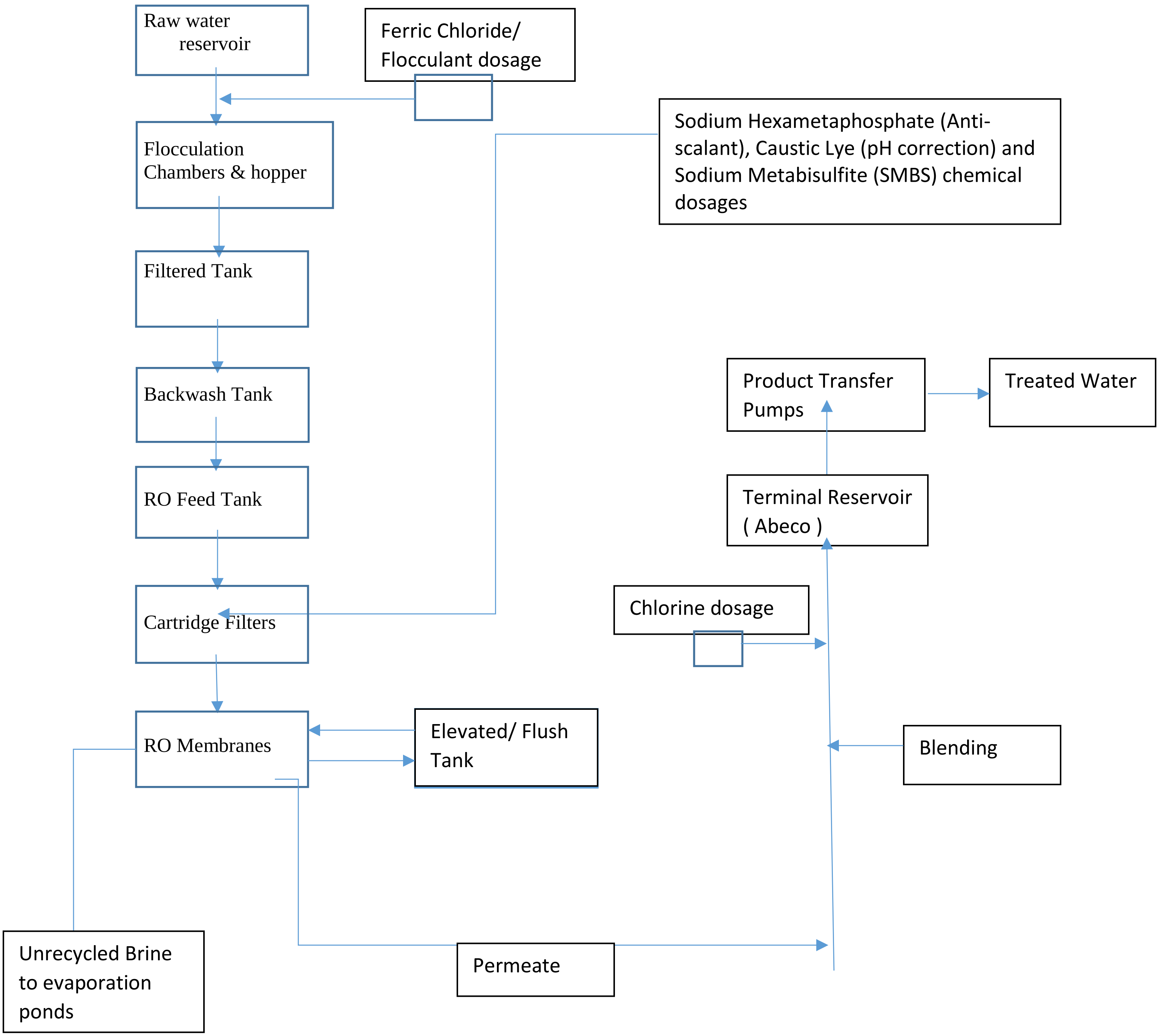


Figure 4. Process flowchart

Pictorial flow process


Raw water concrete Reservoir (100m³)

Raw water Feed Pump


Ferric dosing


Flocculation Static Mixer


Flocculation Chambers

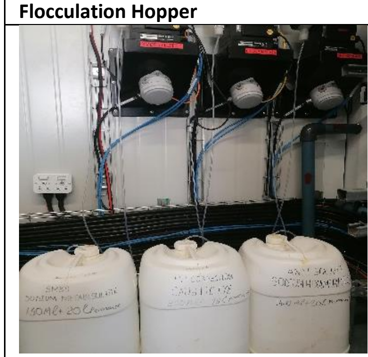

Flocculation Hopper

Filter Feed Tank


Sand Filtration


Backwash Tank

RO Feed Tank


Chemical Dosing


High Pressure Pump


Cartridge Filter (5 micron)


RO Membranes (ESPA2 4040)


Permeate Elevated Tank

				
Chlorination	**Potable feed tank**	**Abeco**	**Brine (Reject) Ponds**	**HMI**

Figure 4. Process flowchart

- From the RO membranes permeate and brine are produced. 50% of the brine gets recycled and fed back to the membranes; the other 50% is discharged to the ponds.
- Permeate is pumped through to the elevated permeate tank, the water then run through the dosing pump of chlorine and taken to the potable feed tank.
- Blended water is trapped from the filter tank and mixing with the permeate of set ratio for re-mineralization purposes.
- Permeate + blended water makes up the final water with added chlorine then to the potable feed tank and the potable feed pumps take to the final water reservoir, then to the community.

NB: At the membrane RO feed (input stage) the following parameters have to be considered; conductivity, pH, temperature, feed flow rate and feed flow pressure.

Output stage the considered parameters are; pressure, flow rate, conductivity and pH for the permeate and brine.

TEST PARAMETERS

Table 3 plant testing parameters

PARAMETER	**Raw water**	**Filtered water**	**RO Feed**	**Permeate**	**Brine**	**Final Water**
Conductivity	x	x	x	x	x	x
Turbidity	x	x	x	x	x	x
PH	x	x	x	x	x	x
Flow rate	x	x	x	x	x	x
Temperature	x	x	x	x	x	x
Hardness						
CHEMICALS						
Fluoride	x	x	x	x		
Nitrate	x	x	x	x		
Chlorine						x

Sensitive conditions

1. Pressure increase beyond +13 bars
2. Conductivity (high correlation of pressure)
3. pH high when the feed flow pipe there's no water (sensor issues)

When the pressure is high the first we check the RO feed flow rate (1.95) and the recovery (recycled brine) flow rate (0.5).

RO feed flow rate ranges between 1.94-1.97

Recycled brine flow rate range 0.50-0.55

To control your pressure, you must check your Burkert value whether is on manual/Auto, if it is on Auto change to manual operation and then can change the values to the set of required flow rate. High conductivity is contribution of where the raw water is being source or the impact of recycling a lot of brine water.

CLEANING PROCESSES

The plant is incorporated the two main cleaning processes backwash for cleaning sand filters and CIP for cleaning the RO membranes.

Backwash

Backwash is carried out when the turbidity of filtered water is high 0.13 NTU. The backwash can be operated automatically using the Human Machine Interface (HMI) panel with a set to test of maximum 7 min however the operator can stop it when sees that the water is clean via the transparent pipe.

Cleaning In Place(CIP)

CIP is carried out when the membrane pressures are high or when the operator feel the need to clean the membrane; the low pH is 2.0 and the high pH is 12.0 and the recommended low pH range is 2-4 pH and 10-12 High pH cleaning; when carry out the high pH you use caustic, when carrying out the low pH you use hydrochloric acid. The CIP operation procedures are as follows:

1. The CIP pump shall be placed in one of three modes (Automatic, Manual and Off) on the HMI and during automatic mode the pumps will operate as follows:
    1. The operator must activate the CIP operation on the HMI Panel
    2. Then the three-way valve in the permeate line will open and the RO feed duty pump will start to fill the CIP tank to 75%.

3. Once the water reached the set level the heater turns on.
4. The operator should select on the HMI the chemical mixing based on the low or high pH operation
5. The solution shall be heated to 40 ^{o}C
6. Cleaning shall be conducted first at a low pH of 2-3.
7. The CIP will drain as much water from the RO system as possible by monitoring the conductivity level in the brine line.
8. Once the system is flushed close the burkert valve(DV-004) and open BLV-029 and reroute the cleaning solution back to the CIP tank. The permeate will also be routed back to the CIP tank.
9. Circulate the cleaning the solution as low flow of 1.14m^3/h for 30 minutes
10. Increase the flow rate to a moderate flow of 2.28 m^3/h for 30 minutes
11. Increase the flow rate to high flow of 4.6 m^3/h for 45 minutes
12. Stop the pump and soak for 45 minutes
13. Circulate at 4.6 m^3/h for 60 minutes
14. Monitor the pH of the cleaning solution periodically to make sure it has not risen above the pH of 3.5. Add more low pH cleaning chemical if necessary.
15. Drain the cleaning solution and rinse with fresh clean water
16. Next step is to perform a High pH cleaning following the same procedures above but this time using a high pH cleaning Chemical solution at a pH of around 11.
17. When cleaning is completed place the RO plant back in service.

Manual CIP operation

1. The operator must the select manual button on the HMI
2. During manual operation the CIP pump can be switched on and off as desired with the HMI

PLANT DAILY ACTIVITIES

Daily plant operation activities that the operators and the UNAM team were involved are shown in the table below.

Table 4 plant operational schedule

Time	Activities	M	T	W	T	F	S	S
05:00-07:30	Measuring rest water level of the boreholes	x						
06:00 -06:15	Analyze the record/ report of the previous shift	x	x	x	x	x	x	x
06:20 -06:30	Inspection and data recording	x	x	x	x	x	x	x
06:30 -06:50	Chemical mixing	x	x	x	x	x	x	x
07:00	Start the Plant	x	x	x	x	x	x	x
07:10	Open the meter to the community and service	x	x	x	x	x	x	x
09:00-09:30	Close the meter to the community and service	x	x	x	x	x	x	x
09:40- 14h00	Monitoring and running the plant(backwash, CIP, Levels, Pressure, PH, Turbidity, Conductivity)	x	x	x	x	x	x	x
10:00-11:00	Sampling, testing and data recording	x	x	x	x	x	x	x
11:00-12:00	Housing Keeping	x	x	x	x	x	x	x
12:00- 13:00	Measuring pump water levels for the boreholes	x	x	x	x	x	x	x
13:00 -14:00	Shift handover/inspection	x	x	x	x	x	x	x
14:30-21:00	Monitoring and running the plant(backwash, CIP, Levels, Pressure, PH, Turbidity, Conductivity)	x	x	x	x	x	x	x
15:00-16:00	Sampling, testing and data recording	x	x	x	x	x	x	x
16:00-17:00	Housing Keeping	x	x	x	x	x	x	x
17:00-18:00	Chemical mixing	x	x	x	x	x	x	x
20:30-21:00	Data capturing/incident reporting	x	x	x	x	x	x	x
21:00	Stop the Plant	x	x	x	x	x	x	x
Operations with Generators								
05:00	Start the generator							
09:30	Switch the power generation mode							
16:00	Start the generator							
21:00	Stop or refill the generator							
02:00	Stop or refill the generator							

The plant operation can be carried out via the automation programmable logic controller (PLC) or the manual operation using a HMI panel. The plant is designed and built to be operated in a fully automated manner. The starting and stopping of the plant is done by pressing the button on the home page of the HMI. The pumps and valves(ZIC) of the of the raw water, filtration, RO, Potable water, CIP and Backwater are operated on automatic or manual on the HMI Panel except the operations of burkert valve which has it is own interface.

DATA COLLECTION

The plant consists of the 7 sampling points from where samples can be collected for lab testing. The sampling points with their labels are for raw water(A), filtered water (B), RO feed(C), Permeate(D), Brine(E), Final(Blended) water(F) and product water(G). There are various installed control instrumentation transmission sensors which are located at various designed points to typically measure Temperature(TIT), Pressure(PIT) and Flow rate(FIT) where records can be obtained on the in-line.

Others data are obtained from the HMI panel which is referred to as online data (SCADA) which are Solar and weather, Pump pressures, flow rates, Temperatures, PH, Turbidity, Electrical Conductivity, Tank/reservoir levels. The HMI has incorporated a monitoring alarm system for PH, Pressure, Turbidity which first gives the warning (Yellow display) and if nothing has changed then an alarm (Red display) will trigger and the plant will automatically shut off. The warning and alarm happens only when the aforementioned parameters are beyond the set required values. The renewable energy data can also be obtained on victron color controller device and AcuDC240 data logger which are installed in the ventilated battery and inverter room.

HYBRID RENEWABLE ENERGY

The Grunau Desalination Plant is powered by stand-alone solar photovoltaic (PV) - Wind turbine hybrid system. The solar system is made up of 64 units of 300Wp (Watts Peak) Canadian solar photovoltaic modules, which are installed on the roofing structure whereby 32 modules faces East and the other 32 faces West. The modules are set to produce a maximum of 19.2 kWp, which are controlled by 4 victron charge regulators, charging 140kWh Lithium Ion Phosphate battery.

The plant has one wind turbine comprises of three blades with the rating of 800Wp, elevated at 12m high to maximum harvest of available wind energy. The hybrid energy from the solar and wind are stored in the battery. The battery stored energy is extracted by the 3 x 5kVA victron inverters, which provides a maximum of 15kVA 3-phase power to the water desalination plant.

DATA ANALYSIS

The recorded data captured May-July 2021 as analyzed as follows.

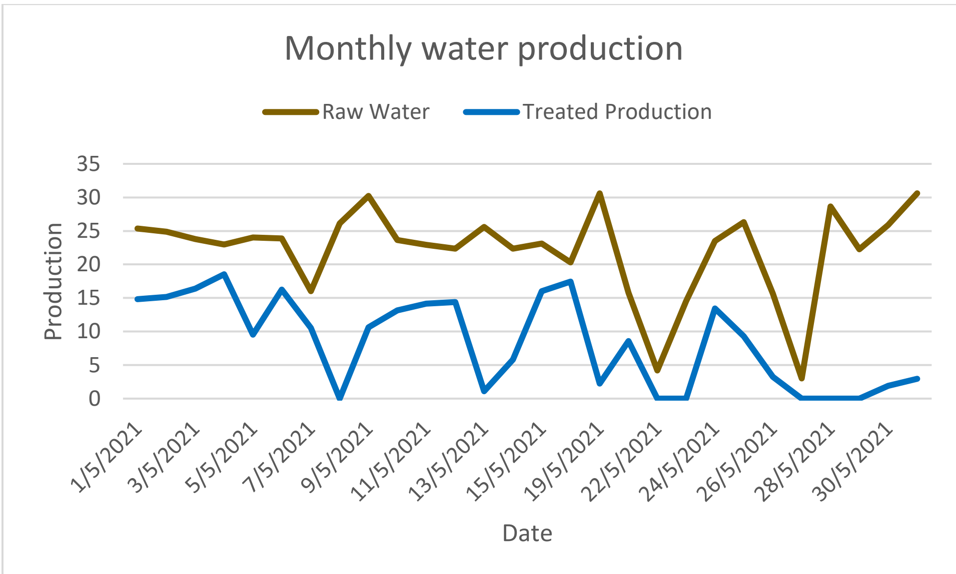


Figure 5. May water production

The May raw water production levels on average is 22.09, the median is 23.57 with the highest water level being 30.61 and the lowest is 3.01. The treated water (terminal levels) on average is 8.41, the median is 9.40, the highest is 18.54 and the lowest being 0 with 0 mode as shown in figure 5 above.

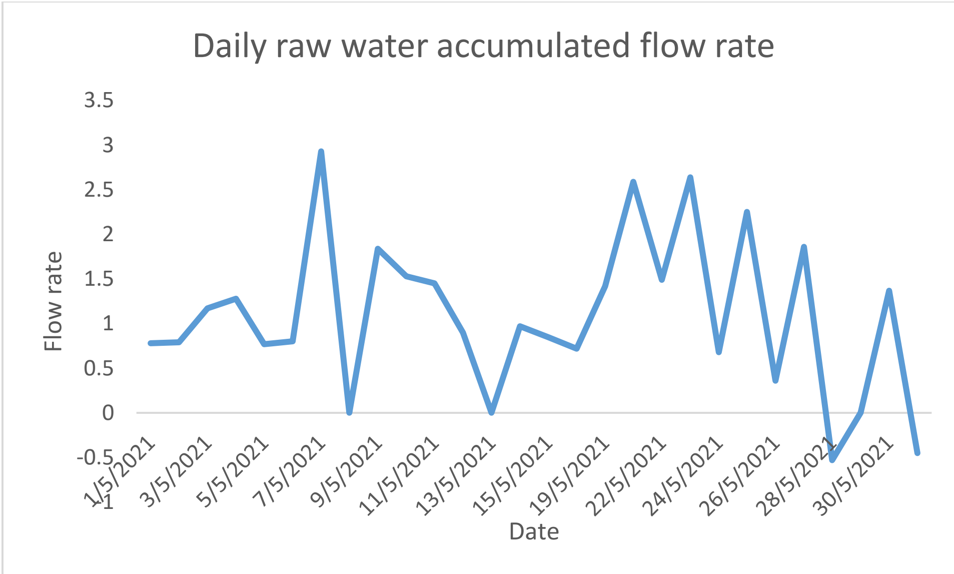


Figure 6. May daily raw water flow rate

The raw water average flow rate is 1.08, the median is 0.93 with the highest raw water flow rate being 2.93 as indicated in figure 6 above.

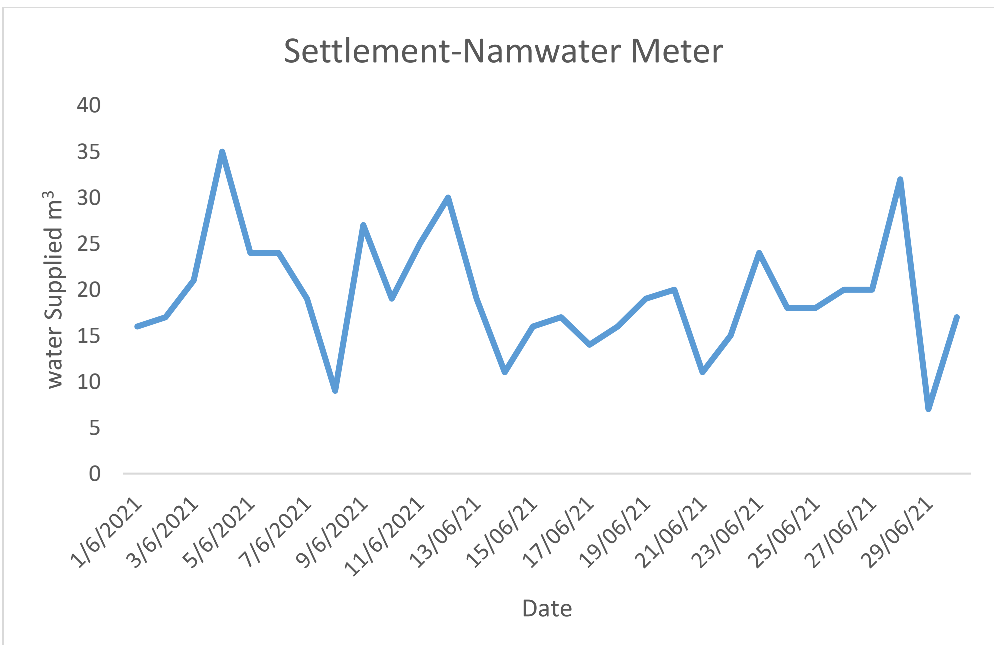


Figure 7. June daily settlement meter flow rate

The water supplied to the settlement is recorded to have an average of 19.33, the median is 19, the highest is 35 and the lowest 7 as reflected in figure 7 above.

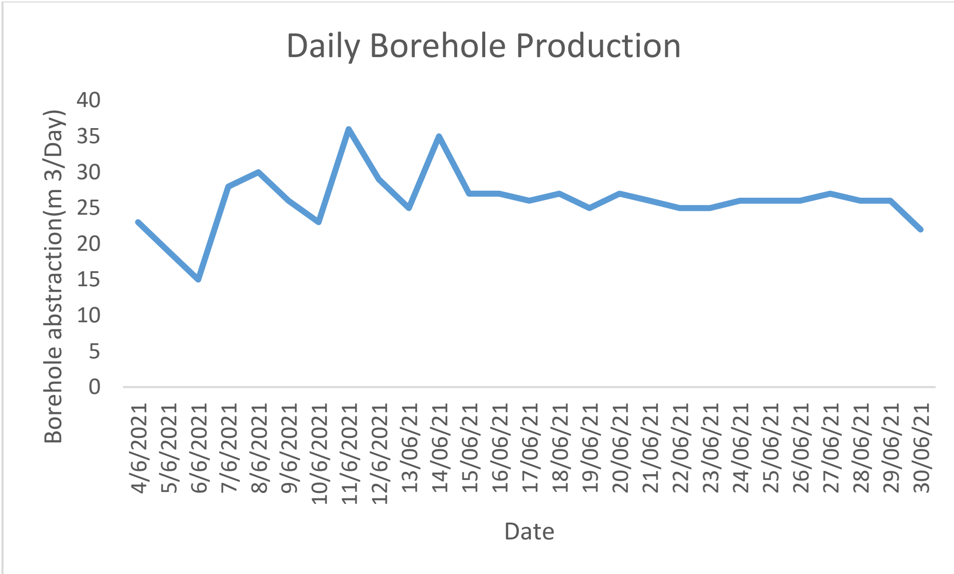


Figure 8. June daily borehole production

The borehole daily water abstraction on average is 26.04, the median is 26, the highest 36 is the lowest is 15, the mode is 26 as shown in figure 8 above.

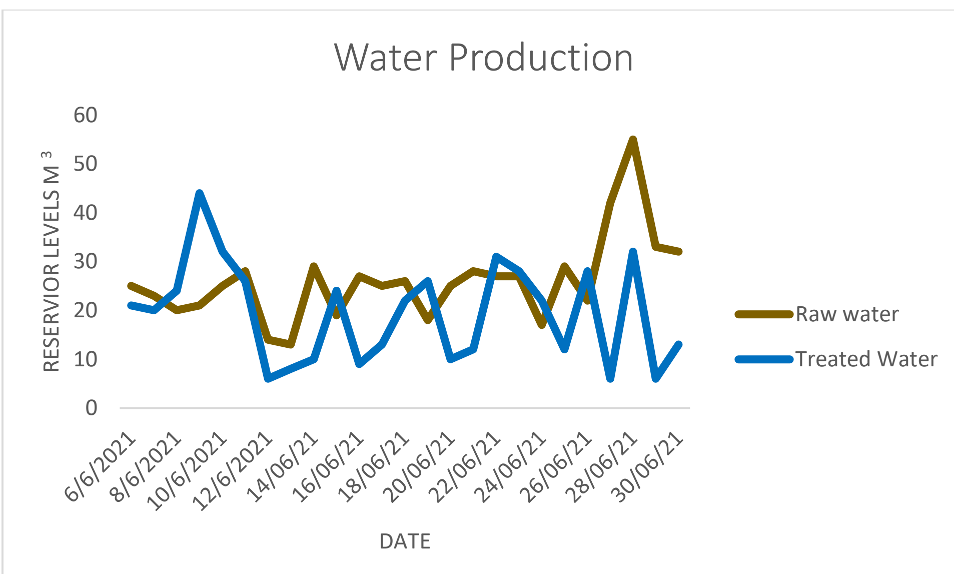


Figure 9. June daily water production

Raw water production levels on average is 26, the median is 25, the highest is 55 and the lowest is 13 and the mode is 25. The treated water (terminal levels) on average is 19.4, the median is 21, the highest is 44 and the lowest is 6 and the mode is 6. With provided data we can be able to confirm that the water production with records from the borehole abstraction, the raw water levels, the treated water and the supplied water to the community there are correlations as highlighted in the figure 9 above.

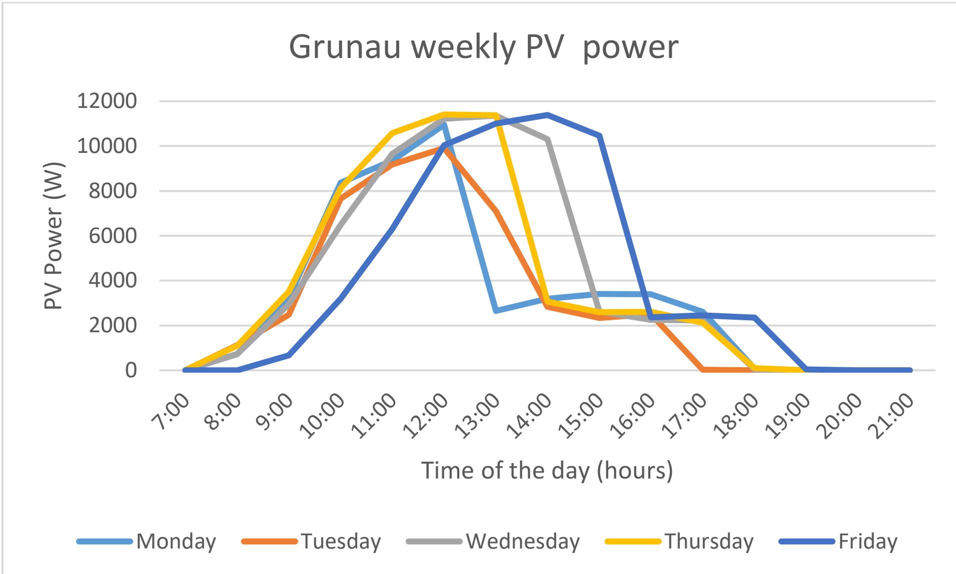


Figure 10. June weekly PV power

The median power produced by the PV is 2456W, the mode is 0 and the sum power produced was 269756W as indicated in figure 10 above.

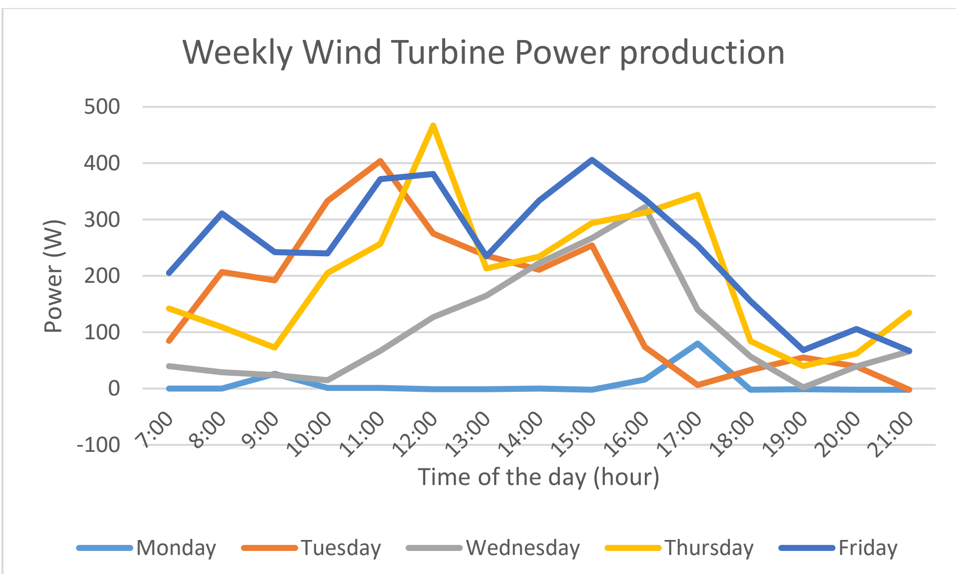


Figure 11. June weekly wind turbine production

The median wind turbine power is 106, the mode is -2 and the weekly wind turbine power is 10781 as reflected in the figure 11 above.

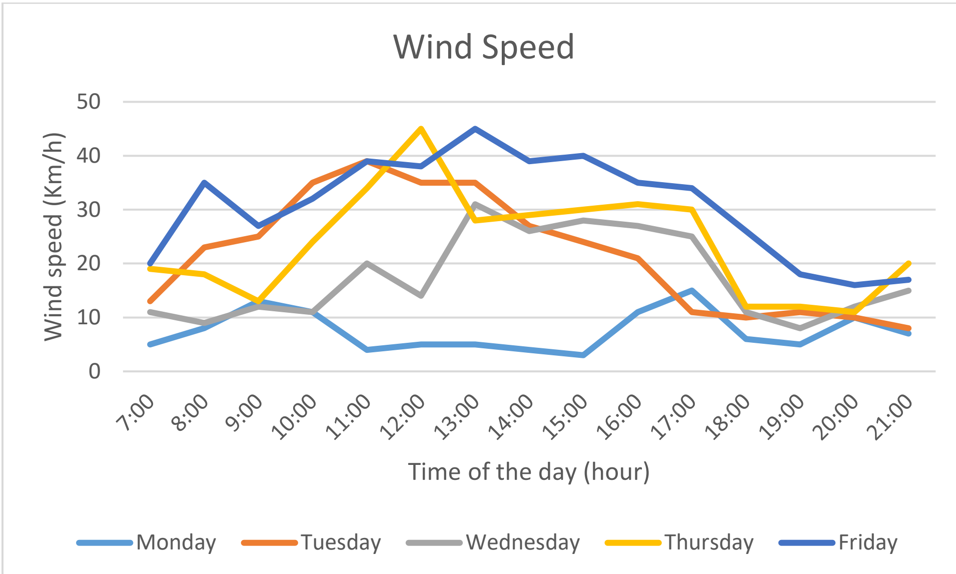


Figure 12. June daily wind speed

The median wind speed is 18 km/h; the mode is 11. The highest weekly wind speed occurred on Thursday and Friday which is 45 km/h and the lowest occurred on Monday of 3km/h as reflected in figure 12 above.

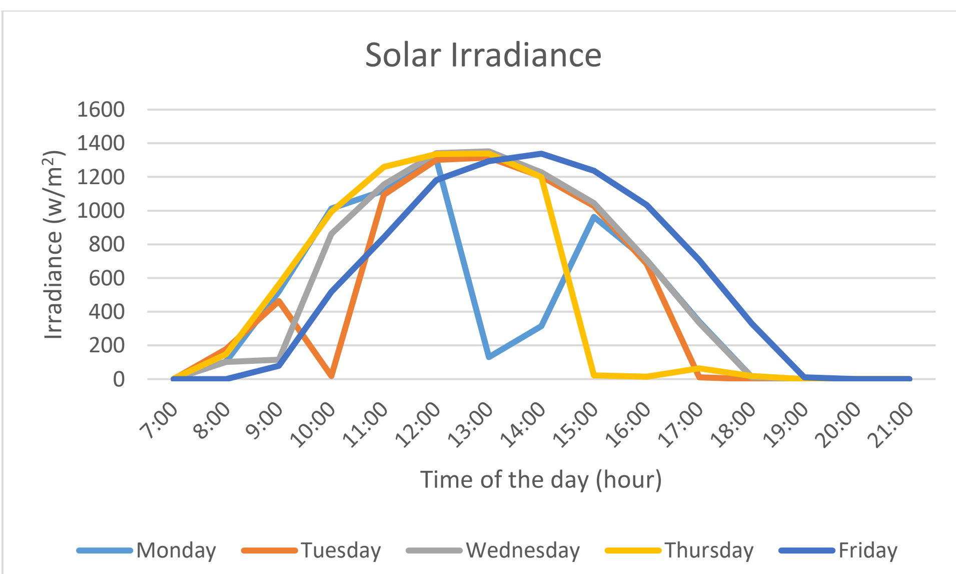


Figure 13. June daily solar irradiance

The median is 315 and the mode is 0. The highest irradiance occurred on Wednesday which is 1339w/m^2 and the lowest irradiance is 0 as highlighted in the above figure 13 .

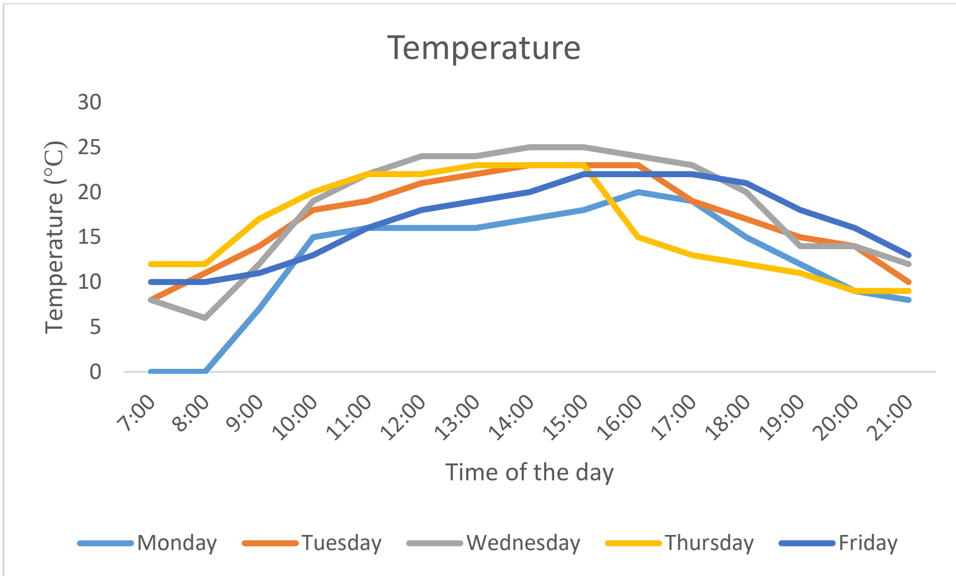


Figure 14. June daily temperature

The weekly median is 16 centigrade and the mode temperature for the week is 22. The highest temperature recorded during the week occurred on Wednesday which is 25°C the lowest temperature recorded during the week is 0°C as indicated in figure 14 above.

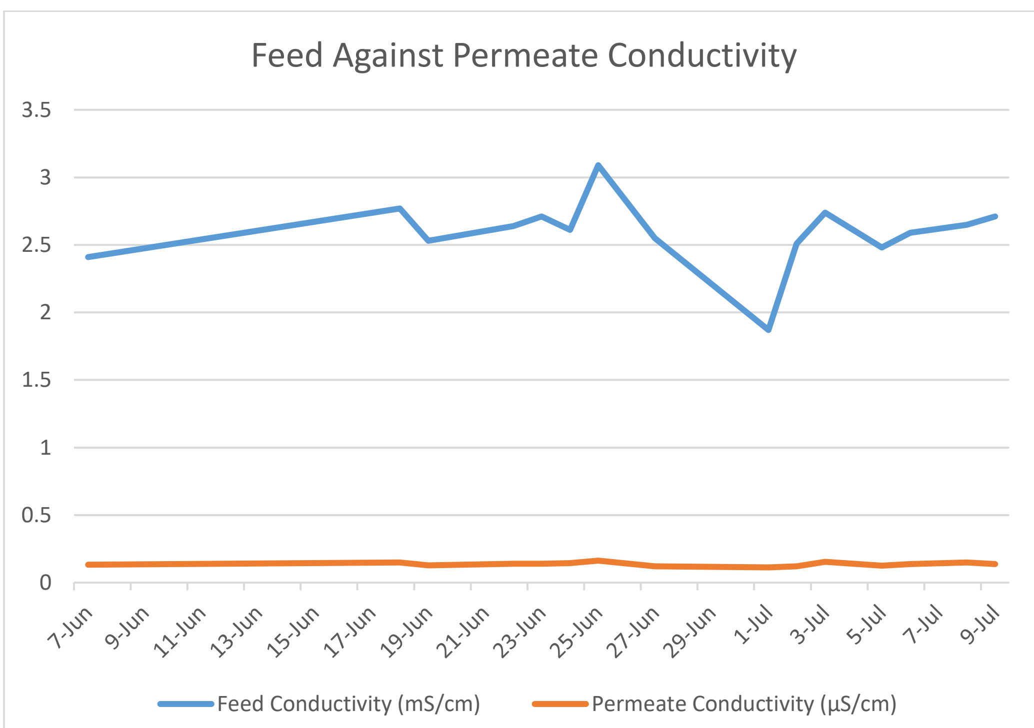


Figure 15. Daily feed against permeate conductivity

Data depicts average daily electrical conductivities. Maximum and minimum difference between the feed and permeate conductivities is 2.93mS/cm respectively. The average feed conductivity is 2.59 mS/cm whereas the average permeate conductivity is 0.14mS/cm as shown in figure 15 above.

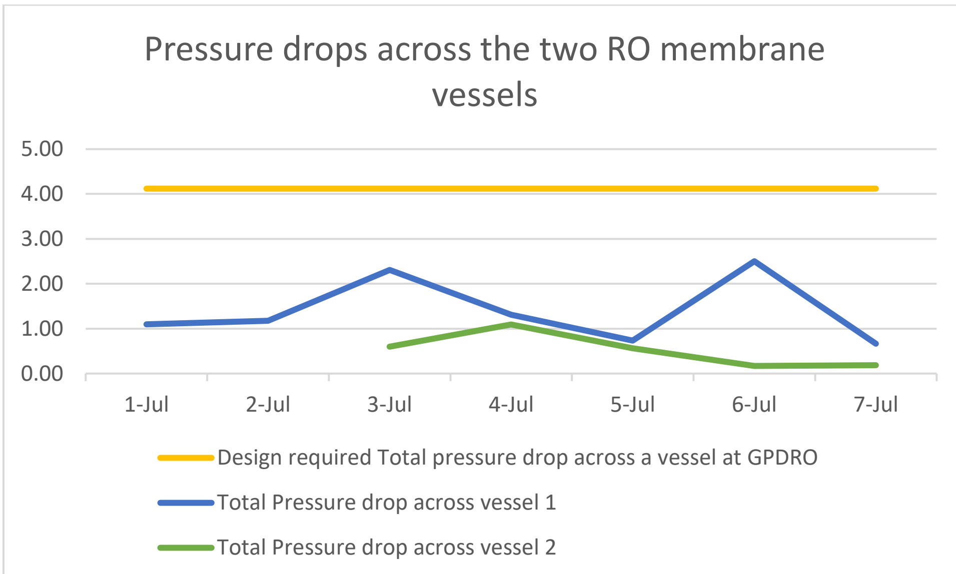


Figure 16. Daily feed against permeate conductivity

The graphs depict average pressure drops across membrane vessels per day. Maximum pressure drops across vessels 1 and 2 are 2.50 and 1.09 bars respectively whereas the minimum pressure drops are 0.67 and 0.17 as depicted in above figure 16.

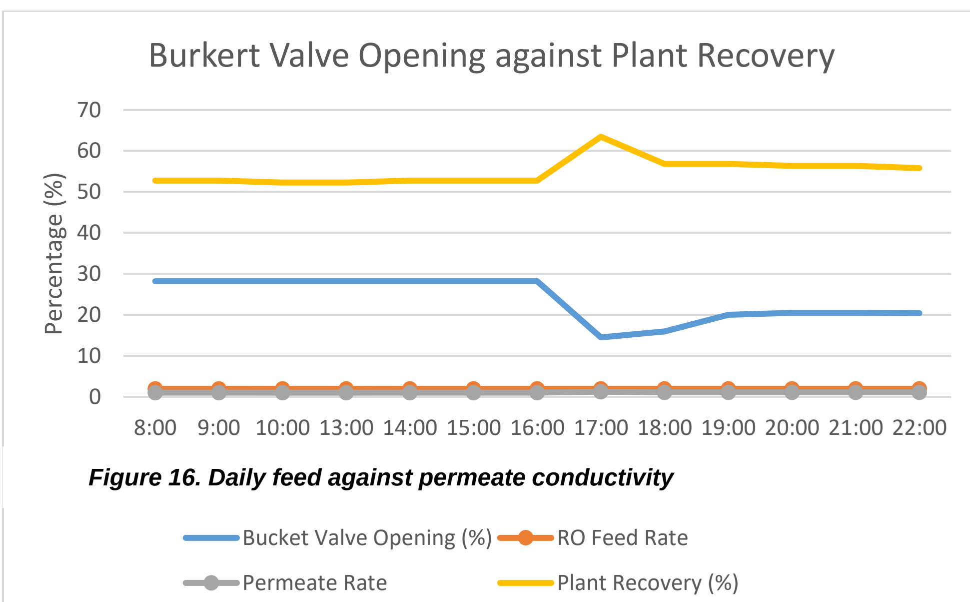


Figure 16. Daily feed against permeate conductivity

Figure 17. June daily burkert valve opening

The graph above clearly outlines an inverse relationship between a bucket valve and plant recovery. Minimum burkert valve opening is 16% at the same time the plant recovery is at a maximum of 56.85%. Maximum burkert valve opening is 28.2% at the same time plant recovery is 52.79% as indicated in figure 17 above.

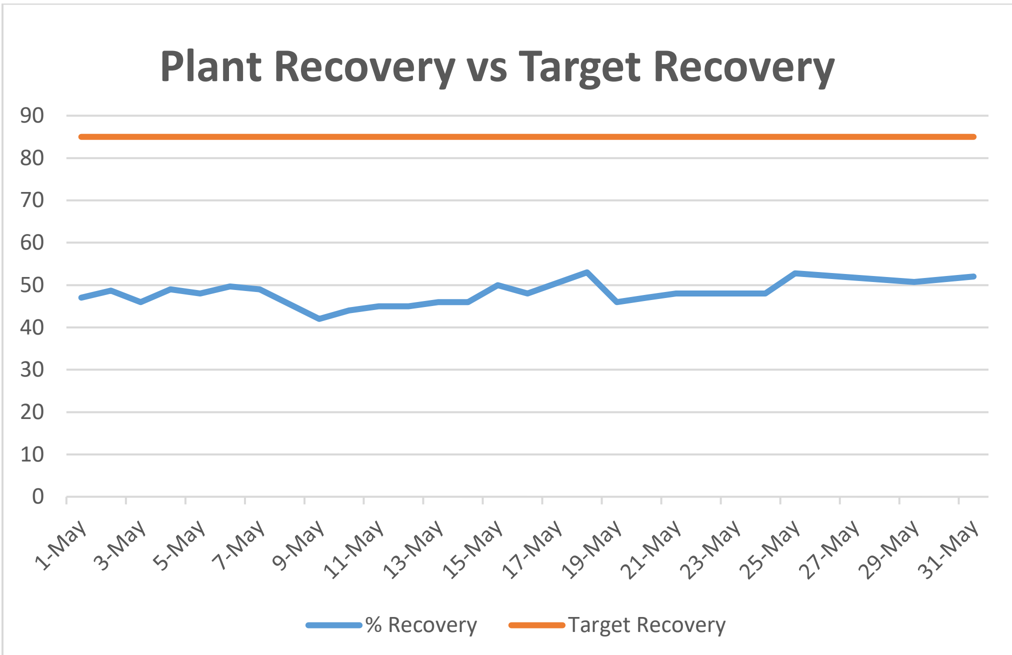


Figure 18. comparison between plant and target recoveries

Target recovery ranges around 85.5% whereas the plant recovery is about 56%. A clear reflection of variation between design parameters and operational parameters as reflected in figure 18 above.

FINDINGS AND RECOMMENDATIONS

During the six weeks' attachment duration, the team has made various observations:

- The weather pattern is very unpredictable as there were rainy, foggy, windy days of which have impacts of reducing the raw water abstraction from the boreholes and therefore affect the final water product of the plant. The Concrete reservoir can only supply water when the level is 18 m^3 and above as below this level will results in the raw water pump sucking in air hence the recommendation to install an air release valve.

- Due to constant fluctuations in weather patterns, alternative sources of energy would be recommended such as battery storage system or generators in order to increase current $26m^3$ borehole daily abstraction.
- While carrying out CIP an observation was made whereby the cartridge filter house was found without cartridge. Some sensors are malfunction such as the brine recovery and backwash level, therefore the recommendation to carry out the inspections from time to time. In addition, the CIP tank steering (mixing device) need to be fixed and enable to operation automated.
- The raw water flow meter is set to be $2.3m^3/h$ and the product water is set to be 1.9 m^3/h making the 82% efficiency, however upon critical analysis we found that the product flow is around 1.4 m^3/h which make the efficiency to be 60%. This was also back up by the average accumulation of the product produced per hour as 2% as reflected on the HMI Abeco levels. Therefore, we recommended the technical team to consider and perhaps work out the correct values or settings of the flow meters.
- When the Burkert valve is on Auto mode the pressure keeps increasing instantly which result in pressure warning and alarm and hence shut off the plant. The burkert valve has to be operated in manual and this requires constant monitoring.
- The Data recording system (SCADA) is not functional hence the data recordings have to be taken manually. The wind turbine data cannot be displayed on the HMI panel because the sensors are not connected. The operators need training in data recording and keep as well as basic computing skills to keep with this tasks in the meantime.
- The 64 panels will require a scheduled cleaning practice as per recommended guidelines and the operator may need to be training on the cleaning procedures. This exercise is observed to be important to remove dust and other accumulative particles on the panels surfaces from time to time in order to maximize solar energy production efficiency.

SURVEY

Based on the current observation, water distribution and consumption of treated water by the desalination plant is complex and difficult to meet the demand of the community. The provided minimum water needs to be equally and fairly distributed and responding to the community lifestyle.

The objectives of the survey are:

1. To work out the formulation of balancing the plant operation and water distribution by determining the quantity of water usage of the community.
2. To plot out the water distribution based on daily water need.

Therefore, ensure that the raw water obtain is treated all the time before distribution and the plant operations is continuously running and finally always maintain treated water for reservation for use in case of emergencies or crisis.

Ponds

The observation was made the ponds are in the state were some animals get trapped in and dead, hence amendments on the fencing needs to be considered to prevent access for small animals. Due to the fact that the ponds are open, lots of dirty are blown in during windy days and there is a need to have a cleaning exercise schedule from time to time as depicted in figure 19 below.

Filled up receiving pond	Spotted snake trapped in the pond	Dead squirrel & dirty in the Pond

Figure 19. Evaporation ponds conditions

Research work to be completed

1. Performance Analysis of RO Membrane: Grunau Desalination Plant

This study is based at the Grunau Pilot Desalination Reverse Osmosis plant. Grunau settlement located at the Southern part of Namibia comprises of about 521 citizens, which depends on underground water for consumption or usage. The rare use of membrane technology prompted the undertaking of this study. To carry out the study operational data is collected on an hourly basis, the student familiarized himself with the membrane design parameters. Comparison between design and operational parameters is made to determine any existing deviations. Calculations such as membrane salt passage are to be carrie1d out. The RO membrane system operates on mere constant conditions, this coupled with the vessels being new, one would expect constant outputs. However, as is with every system, the design parameters do not always match operational parameters hence the need to undertake the study.

2. Modelling and simulation of PVRO desalination plant.

Due to constantly changing weather in Grunau community, the production flow of the desalination is badly affected. The aim of this research work is to model simulate the PVRO desalination system of the Grunau Pilot Plant and enable prediction of permeate flow production based upon instantaneous PV available power. Feed concentration, temperature and pH will be assumed constant in this work. PV power can change always, it can then be assumed that for a certain PV power, RO process operates differently to produce permeate flow. By accounting this consideration, a diffusion model solution approach for the RO membranes can be used easily in predicting the RO performance.

An overview of basics of solar radiation, PV power generation and RO system will be presented for the instantaneous performance evaluation of PVRO system under different inclination angles of PV panels for this study. The factors affecting the PVRO performance of flat panel, will be analyzed. In addition, permeate collected will be computed and compared to the performance of conventional flat PV panel.

3. Performance Evaluation of a Photovoltaic-Wind hybrid system

The device constitutes of photovoltaic (PV) and wind subsystem, battery energy storage, load and a hybrid system, controller for battery charging and discharging conditions. The system comprises of a 64 x 300W Canadian PV modules, 800W wind turbine. Excess energy produced is stored in a lithium phosphate battery with maximum storage capacity of 140kWh. The average plant production is 36m^3/day. The research was carried in Grunau (South of Namibia). The PV panel incorporate the primary energy supply to the system, while the wind turbine is the secondary supplier from their contribution point of view. It is utmost important to compare the design and the actual system working parameters for certain period of time to precisely evaluate the hybrid system performance.

The objectives of this study is to identify and compare what best method suit the energy supply at Grunau by evaluating the system performance using wind speed, solar irradiance and temperature as working parameters. Identify if the solar and wind turbine are producing the same power as per their design specifications. The study opts to find what parameters affect the PV panels or wind turbine to deliver more or less power. The Results has shown that PV panels at Grunau provides 96.5% of the plant power. Wind speed enhance the turbine power production Regardless of temperature and irradiance. High irradiance above 79W/m2 harness high productivity of PV power.

CONCLUSION

The industrial attachment was worthwhile and the team has learned a lot. However, still a lot need to be done as per the above observations and recommendations. More data are needed to draw much more accurate conclusions on the plant operations, performance analysis for RO and for hybrid renewable energy systems.

APPENDIX 1: WATER CONSUMPTION & DISTRIBUTION SURVEY

Date of survey:		Person asking the questions:	

1 Person answering the survey

1.1 Name		1.2 Male/female	☐ male ☐ female
1.3 Phone number (we ask for phone number in case follow-up clarification is needed)		1.4 Age	
1.5 Marital status	☐ married ☐ separated/divorced /widowed ☐ single ☐ prefer not to say	1.6 Is the person answering the survey the owner of the household?	☐ yes ☐ no
1.7 Address of household			

2 Information on the household

2.1 Number of people in household?	☐ ...... <18 years ☐ ...... 18 to 60 years ☐ ...... >60 years ☐ ...... Total in household	2.2 Number of employed adults in household? (>18years)	☐ ...... full-time ☐ ...... part-time ☐ ...... total
2.3 Who is the owner of household?	☐ man (18 to 60 years) ☐ woman (18 to 60 years) ☐ pensioner (>60 years) ☐ child (<18 years)	2.4 Is there someone living in the household with a disability or serious illness?	☐ yes ☐ no ☐ prefer not to say

3. Water service

3.1 Method of water supply?	☐ Water supply pipes connected to the house. ☐ Collect water from standpipe taps. ☐ Collect water from a neighbor ☐			3.2 Between what hours do you access water?	
3.3 What time do you prefer to receive water?		3.4 How much water do you receive/use on daily basis?		3.5 How much water does your household require daily?	
3.6 What method of water storage do you use?	☐ Tank ☐ Drums/Bucket ☐ Others			3.7 What is the storage capacity do you have and how long does the stored water last?	
3.8 What do you use water for?	☐ Domestic ☐ Irrigation ☐ Leisure ☐ Others	3.9 Do you have flushing toilets?	☐ Yes ☐ No	3.10 How much water does your household require daily?	
3.11 What day/s of the week do you use more water?		3.12 What water harvest mechanism do you use?		3.13 What water saving strategies do you use?	☐ Reduce ☐ Reuse ☐ Recycle ☐ others

4. Other comments and feedback

4.1 Do you have any other comments or feedback on the water consumption or distribution?

APPENDIX 2:DATA SHEET

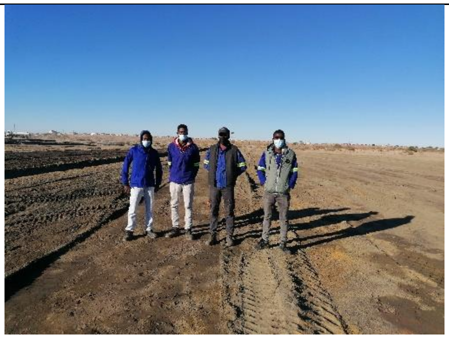
GRUNAU DESALINATION PLANT DAILY REPORT												
OPERATOR NAME:								SIGNATURE:				
	SETTLEMENT			SERVICE STATION		PRODUCTION				RESERVOIR LEVEL %		
DATE:	Settlement Meter	Namwater Meter	Difference /Day	Meter	Difference / Day	Boreholes (FIT 001)	Difference	RO Plant (FIT018)	Difference /Day	Raw water	Terminal	Free Chlorine mg/l
01/06/21			16	291	0	8259		2176		25	14	
02/06/21		116225	17	301	10	8278	19	2190	14			0.80
03/06/21	53321	116242	21	301	0	8341	63	2204	14			
04/06/21	53356	116263	35	301	0	8364	23	2221	17	19	27	
05/06/21	53376	116298	24	310	9	8383	19	2235	14			0.39
06/06/21	53398	116322	24	310	0	8398	15	2237	2	25	21	0.23
07/06/21	53416	116365	19	310	0	8426	28	2251	14	23	20	0.10
08/06/21	53424	116374	9	310	0	8456	30	2264	13	20	24	0.24
09/06/21		116401	27	310	0	8482	26	2279	15	21	44	0.78
10/06/21		116420	19	310	0	8505	23	2297	18	25	32	0.35
11/06/21		116445	25	320	10	8541	36	2314	17	28	26	0.15
12/06/21		116475	30	320	0	8570	29	2332	18	14	6	0.04
13/06/21		116494	19	320	0	8595	25	2337	5	13	8	0.42
14/06/21		116505	11	337	17	8630	35	2340	3	29	10	0.50
15/06/21		116521	16	337	0	8657	27	2350	10	19	24	1.0
16/06/21	53577	116538	17	354	17	8684	27	2363	13	27	9	0.10
17/06/21	53590	116552	14	364	10	8710	26	2364	1	25	13	0.20
18/06/21	53605	116568	16	364	0	8737	27	2373	9	26	22	0.39
19/06/21	53623	116587	19	364	0	8762	25	2373	0	18	26	0.78
20/06/21	53641	116607	20	386	22	8789	27	2395	22	25	10	0.50
21/06/21	53651	116618	11	386	0	8815	26	2396	1	28	12	1.0
22/06/21	53666	116633	15	386	0	8840	25	2410	14	27	31	0.10
23/06/21	53687	116657	24	392	6	8865	25	2430	20	27	28	1.90
24/06/21	53704	116675	18	404	12	8891	26	2443	13	17	22	0.60
25/06/21	53721	116693	18	404	0	8917	26	2457	14	29	12	0.31

DATA SHEET : GRUNAU DESALINATION PLANT																
OPERATOR NAME:								**SIGNATURE:**			**DATE:06 July 2021**			**SHIFT:**		
											PLANT FEED		**FILTER FEED**			
RAW WATER	**Time**	**Flow rate**	**Turbidity**		**Conductivity**		**PH**		FIT-001		FIT-004	Flow	FIT-007			
		FIT-001	Online	Lab	Online	Lab	Online	Lab	S:9173		S:2798		Online	S:3506		
	07:34	0	0.51		2.05		7.97		E:9198		E:2826		2.35	E: 3542		
	12:30	2.74	0.52	0.25	2.03		7.96	7.19	D:25		D:28			D: 36		
	14:00	3.53	0.53	0.16	2.04		7.92	7.22								
RO FEED		FIT-013							FIT-013		**RO PRESSURE**			Unit: Bars		
	07:34	1.97							S: 3106		Time			07:34	12:30	22:00
	12:30	1.97	0.17	0.31	2.48		8.35	7.94	E:3130		Pressure before Cartridge(PIT-001)			11.41	11.24	11.32
	14:00	1.97		0.22	2.42		8.31	7.97	D:24		Pressure after Cartridge(PIT-002)			11.31	11.19	11.26
PERMEATE		FIT-014									RO stage 1 inlet pressure(PIT-003)			11.30	11.13	11.21
											RO stage 1 outlet pressure(PIT-004)			0.19	0.19	0.19
	07:34	1.03			122		7.76				RO stage 2 Inlet Pressure(PIT-005)			10.08	9.97	10.06
	12:30	1.03		0.08	126		7.61	6.27			RO stage 2 outlet pressure(PIT-006)			0.16	0.16	0.16
	14:00	1.04		0.07	124			6.35								
									FIT-014		FIT-008 flow to blended water			Reservoirs levels %		
									S:1338		0.48		S: 996	Raw	Final	
									E:1350		0.47		E: 1001	42	24	
FINAL WATER									D:12				D:5	41	13	
		FIT-018							Free Chlorine	FIT-018	FIT-009 Flow to backwash Tank			43	32	
	07:34	1.90	0.36	0.08					0.3	S:2575	1.86		S:2703			
	12:30	1.91	0.31				7.63	7.14		E:2596	1.87		E: 2723			
	14:00	0	0.32	0.12			7.6	7.14		D:21			D:20			
											BRINE RECOVERY		**BRINE PRESSURE**			
BRINE		FIT-015							FIT-015		FIT-010 water meter		Brine Pressure(PIT-007)			
	07:34	0.95			5.06				S:1955		Flow	S:1024	9.15			
	12:30	0.948		0.17	5.05			7.95	E:1966		0.48	E:1024	9.24			
	14:00	0.942		0.22	4.89			7.91	D: 11		0.48	D:0				
Comments:																

POWER AND ENERGY								
EQUIPMENT	**kWh-Plant startup**	**kWh-Plant shutdown**	**Total Energy for today (kWh)**	**Solar yield for the day kWh**	**Wind Turbine yield for the day kWh**	**Battery state of charge-Shutdown (%)**	**Battery state of charge-shutdown (%)**	**Global irradiation (W/m^2)**
HMI								

APPENDIX 4: PICTORIAL REFLECTION

			
UNAM team	**Rest/ pump water level measurement**	**Solar panel installation**	**Borehole Installation**
			
Borehole rehabilitation	**Lab testing**	**Plant operation training**	**Flocculation Hopper maintenance**

			
Catridge Filter replacement	**CIP Operation Chemical Mixing**	**Bethanie Evaporation Pond Site**	**UNAM Team visit to Bethanie**