

DESALINATION TECHNOLOGY APPROACH TO SUPPORT A SUSTAINABLE FRESHWATER SUPPLY IN PT AMMAN MINERAL NUSA TENGGARA

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ABSTRAK

Air adalah sumber kehidupan untuk manusia dan seluruh makhluk hidup yang tinggal di planet bumi. Ketersediaan air tawar adalah sangat krusial, terutama untuk orang-orang yang tinggal di wilayah krisis air dengan daya dukung sumberdaya air yang rendah. Situasi yang sama pun terjadi di lingkungan PT AMMAN Mineral Nusa Tenggara (disebut PT AMNT) dimana perusahaan masih terus berupaya untuk menyeimbangkan permintaan air tawar dan pasokannya khususnya sehubungan dengan beberapa proyek ekspansi besar yang sedang berlangsung di Batu Hijau. Terdapat beberapa peningkatan permintaan air tawar apakah untuk kegiatan konstruksi maupun operasional di masa mendatang untuk mengakomodasi kebutuhan penambahan tenaga kerja, fasilitas-fasilitas baru, dan tambahan air proses. Saat ini, PT AMNT masih mengoperasikan sumur-sumur air tanah di cekungan air tanah Sejorong dengan rata-rata produksi harian sebanyak 9.000-m³/hari dimana proyek-proyek ekspansi besar ini membutuhkan tambahan air tawar hingga 4.500-m³/hari yang akan dipasok dari sumber-sumber air yang baru di luar fasilitas eksisting untuk menghindari pengambilan air tanah yang berlebihan. Pada akhirnya, teknologi desalinasi menjadi solusi alternatif sebagai pilihan terbaik dan menjanjikan dalam wawasan keberlanjutan setelah PT AMNT melakukan berbagai rencana untuk dapat mencadangkan sumberdaya air tanah.

Kata kunci: desalinasi, SWRO (reverse-osmosis air laut), air tawar, membrane filter.

ABSTRACT

Water is the source of life for humans and all creatures living on planet earth. The availability of freshwater is very crucial, especially for people living in water-scarce regions with low water resource-bearing capacity. A similar situation occurs in PT AMMAN Mineral Nusa Tenggara (called PT AMNT) in which the company is in the struggle to equilibrate the freshwater demands versus supplies, especially in line with some major expansion projects in Batu Hijau site. There is an increase in freshwater demands either for the construction phase or future operations to accommodate additional manpower, facilities, and process-water requirements. Currently, PT AMNT is operating groundwater wells in the Sejorong watershed with an average production rate of about 9,000-m³/d in which these major expansion projects lead to any additional freshwater up to 4,500-m³/d that should be supplied from a new water resource out of the existing one to avoid any excessive groundwater abstraction. Finally, a desalination technology becomes an alternative solution as the best option and promising in terms of sustainability point of view after PT AMNT conducted plan to reserve groundwater resource.

Keywords: desalination, SWRO (seawater reverse-osmosis), freshwater, membrane filter.

INTRODUCTION

Several regions in Indonesia are experiencing a groundwater scarcity for a prolonged period with the level of groundwater availability relatively low to very low (deficit) occurring in Bali

and Lesser Sunda islands in Nusa Tenggara region (see Figure 1) (BMKG, 2017). Likewise, the surface water availability from rivers, lakes, and wetlands also experiences a similar issue during prolonged dry seasons. The Indonesian Central Bureau of Statistics (BPS) notified that the raw water to be treated into potable water in Nusa Tenggara come from spring water of about 67.19%, rivers 16.64%, groundwater 14.21%, dam reservoirs 1.95%, and others about 0.96% (BPS, 2020), the problem appears when the dug wells, springs, and rivers run dry. However, the raw water quality to produce freshwater supply decrease over time due to pollution, erosion, sedimentation, flooding, et cetera alongside the watershed area. Even though the class of waterbody in some regions is categorized as Class-III (in poor quality) or worse means the water is just allocated for agriculture and livestock, but not more, according to the Government Regulation (PP) No. 82 Year 2001 regarding “water quality management and water pollution control”. It is an ironic situation where human should consume freshwater referring to the Ministry of Health Regulation (PERMENKES) No. 32 Year 2017 regarding “water quality for sanitation hygiene” or higher specifications as designated by SNI 01-3553-2006 regarding “bottled drinking water” without any jeopardize to human body, on other hand, there are lots of water pollution and low water quality issues in most of rivers in Bali and Nusa Tenggara (KLHK, 2021).

The status of river water quality in Bali and Nusa Tenggara in Year 2016 – 2020 are very poor as shown in the following Table 1 (KLHK, 2021). Mostly, the river quality in Nusa Tenggara are worse than others due to heavily polluted in a prolonged period and need more tens year for recovery if no human intervention. In part of environmental sustainability effort, there are so many programs had been developed by government, private sectors, and non-governmental organizations (NGOs) involving communities to promote water resources and environmental conservation by means of several programs i.e., PROKASIH (clean river program), KEHATI (biodiversity conservation program), PERMATA (water spring protection program), national park, city forest, agroforestry, and others.

Tabel 1 Status of river water quality in Year 2016 – 2020 (KLHK, 2021)

No.	Province	Name of River	Status of River Water Quality				
			2016	2017	2018	2019	2020
1.	Bali	Tukad Ayung	poor	poor	poor	poor	poor
		Tukad Ho	poor	poor	poor	worse	worse
		Tukad Saba	poor	poor	poor	poor	poor
		Tukad Daya	poor	poor	poor	poor	poor
		Tukad Balian	-	poor	poor	poor	-
2.	West Nusa Tenggara	Ancar	-	-	-	-	-
		Dodokan	-	-	-	-	-
		Babak	-	-	-	-	-
		Brangbiji	-	-	-	-	-
		Jangkrok	worse	poor	worse	worse	worse
		Meninting	poor	poor	poor	worse	worse
		Moyo	-	poor	poor	worse	worse
3.	East Nusa Tenggara	Asesa	poor	worse	worse	worse	worse
		Neolmina	poor	worse	worse	worse	worse
		Liliba	-	-	-	-	-
		Benanain	poor	-	-	poor	poor
		Dendeng	worse	worse	worse	worse	worse

Note: worse = heavily polluted and poor = moderately polluted

In this case, the Indonesian government is striving to develop several water resource infrastructures to accelerate growth in some developing regions by means of developing water reservoirs, dams, and irrigation networks. At least, eighteen dams had been constructed in 2015 to 2022 for irrigation and water supply purposes to align with the national water security issue as scattered in Java, Bali, and Nusa Tenggara. Nevertheless, these efforts are still remaining challenges mainly in terms of water resource security and sustainability with all problems in raw water quality. Furthermore, the Indonesian government together with private sectors require to seek another technological approach to fulfill the gaps shortly for domestic and industrial purposes in crisis regions.

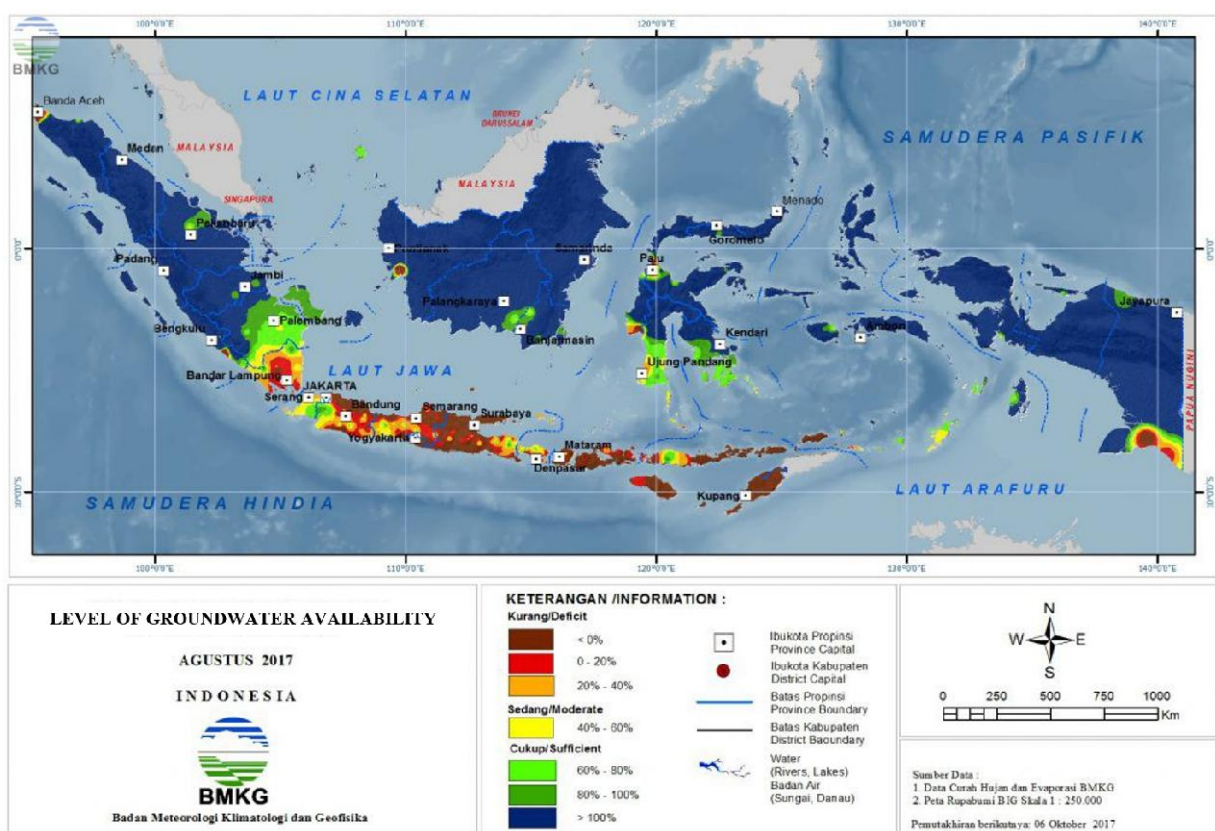


Figure 1 Level of groundwater availability in August 2017 (BMKG, 2017)

METHODOLOGY

a. Water Salinity Classification

In common practices related to salinity terminology, the electric conductivity of water, and total dissolved solids (TDS) concentration, the water is classified into seven classes which seawater is categorized saline water with TDS value of about 35,000 mg/L. The classifications are used to establish in-situ water quality standards for implementing water protection programs, permitting discharges, setting clean up goals at contaminated sites, and technological approaches to develop a water treatment plant to produce freshwater, drinking (potable) water, demineralized-water, or others (USDA, 2007).

Tabel 2 Water classification based on salinity (Sallam and Elsayed, 2015)

No.	Classification	Electric Conductivity ($\mu\text{S}/\text{cm}$)	TDS Concentration (mg/L)
1.	Freshwater (non-saline water)	< 0.7	< 500
2.	Saline water	0.7 – 42	500 – 30,000
3.	Slightly saline water	0.7 – 3.0	500 – 2,000
4.	Medium saline water	3.0 – 6.0	2,000 – 4,000
5.	Highly saline water	> 6.0	> 4,000
6.	Very saline water	> 14.0	> 9,000
7.	Brine water	> 42.0	> 30,000

Tabel 3 Water classification based on TDS concentration ^[9]

No.	Classification	TDS Concentration (mg/L)
1.	Less brackish water	500 – 3,000
2.	Moderately brackish water	3,000 – 10,000
3.	Highly brackish water	10,000 – 35,000

Tabel 4 Water classification based on degree of salinity ^[12]

No.	Classification	TDS Concentration (mg/L)
1.	Freshwater	< 1,000
2.	Brackish water	1,000 – 3,000
3.	Seawater	30,000 – 50,000
4.	Hypersaline water	> 50,000 or that is found in the sea
5.	Natural brine water	> 50,000 to slurries
6.	Discharge brine water	1,000 to slurries

Commonly, an uncontaminated freshwater quality is generally more suitable for human consumption, livestock, other agricultural uses, and most industrial uses. Slightly brackish water may not be suitable for those uses, depending on the relative amounts of the various major ions and trace elements. Brackish, saline, and brine waters are never suitable for human consumption, however, in some cases, the brackish water can be used for livestock, but saline and brine waters never can (USDA, 2007).

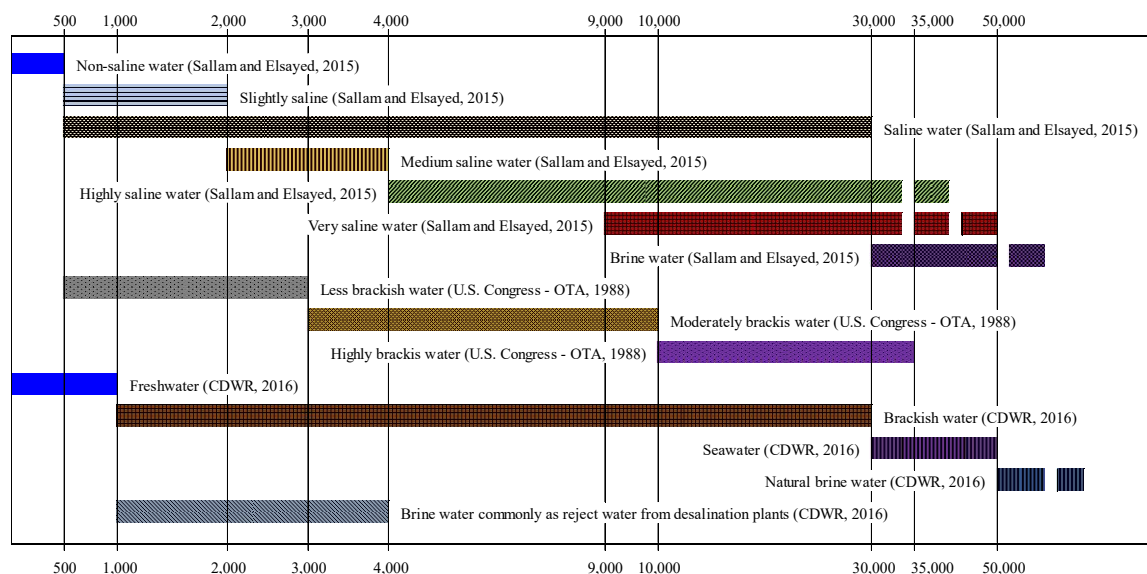


Figure 2 Degree of salinity based on TDS in water (in mg/L or ppm) (Sallam and Elsayed (2015), US – OTA (2008), Gordon (2005))

b. Seawater Quality

Based on the BPS statistical data in 2020, most of the river water qualities in Yogyakarta are categorized as slightly saline water with an average of TDS concentration about 760 mg/L (KLHK, 2021), meanwhile, in Bali, West Nusa Tenggara, and East Nusa Tenggara regions, the TDS on the river waters are 143, 152, and 293 mg/L respectively (categorized as freshwater) without any significant issue on the heavy metal content in these natural river waters.

The Indonesian Sea located between of Pacific Oceans and Indian Oceans with a salinity relatively lower than others as shown on the following map produced by Gordon (2005) with a salinity is about 34.5 ppt or 34,500 mg/L (Gordon (2005); Iskandar & Suga (2022)).

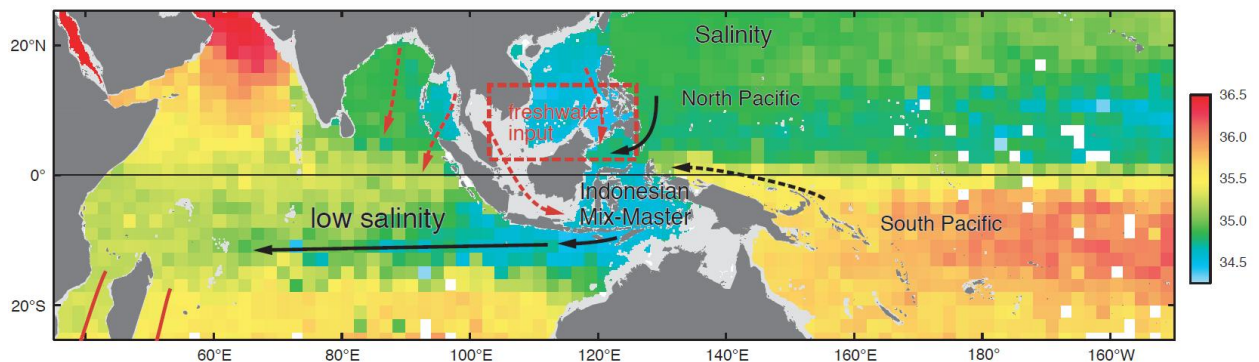


Figure 3 Salinity of the Indonesian Seas^[10]

Based on a seawater sampling taken from the existing intake conducted by AMMAN group from January 2019 to June 2022 in West Sumbawa (West Nusa Tenggara), the seawater quality as nominated desalination feedwater is shown in the following table in which in average the TDS concentration is about 25,010-mg/L, pH is relatively neutral of about 8.0, TSS is very low < 0.7 mg/L (very clear), electric conductivity of about 53,912 μ S/cm, and salinity of about 34,100-mg/L, meanwhile, all heavy metal parameters are still under the design parameter.

Tabel 5 Seawater quality in West Sumbawa as feedwater for desalination

Parameter	Unit	Reference Number	Data History (Jan 2019 – Jun 2020)			Maximum Value
			Max	Min	Avg	
pH	-	6.5 – 8.5	8.3	7.4	8.0	8.5
TSS	ppm	80	3	<0.5	<0.7	80
TDS	ppm	35,000	25,200	24,800	25,010	35,000
Salinity	g/L	80	34.5	34.1	34.1	80
Ammonium, total	ppm	0.3	<0.02	<0.02	<0.02	0.3
Sulphate	ppm	2,635	2,650	2,220	2,321	2,650
Sulphide	ppm	0.03	<0.01	<0.002	<0.004	0.03
Hydrocarbon, total	ppm	1	*	*	*	1
Phenol	ppm	0.002	<0.001	<0.001	<0.001	0.002
PCB (Polychlorinated biphenyl)	ppm	0.01	<0.005	<0.005	<0.005	0.01
Mercury	ppm	0.003	<0.00005	<0.00005	<0.00005	0.003
Cadmium	ppm	0.01	<0.0001	<0.0001	<0.0001	0.01
Copper	ppm	0.05	<0.001	<0.001	<0.001	0.05
Lead	ppm	0.05	<0.001	<0.001	<0.001	0.05
Zinc	ppm	0.1	0.006	<0.005	<0.005	0.1
Clarity	ppm	>3	*	*	*	>3
Odor	ppm	Undetected	*	*	*	Undetected
Total Suspended Matter	ppm	80	*	*	*	80
Oil and grease	ppm	Undetected	*	*	*	Undetected

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Fluoride	ppm	*	6.950	6.400	6.639	6.950
Nitrate	ppm	*	0.006	<0.005	<0.005	0.006
Chloride	ppm	*	19,400	19,100	19,300	19,400
Conductivity	µs/cm	*	57,229	48,984	53,912	57,229
Aluminium	ppm	*	0.013	<0.005	<0.008	0.013
Iron	ppm	*	0.006	<0.005	<0.005	0.006
Manganese	ppm	*	0.002	<0.001	<0.001	0.002
Boron	ppm	*	3.7	3.4	3.6	3.7
Turbidity	NTU	*	1.9	0	0.3	1.9

Note: * Data is not available

RESULT AND DISCUSSION

The desalination is the removal of salts and dissolved solid minerals from water to produce water of lesser salinity than the source water. This term is commonly used to reduce salinity in many sources of water including surface water (i.e., seawater, river, and lake), groundwater, and municipal wastewater. It can be used also to produce potable water uses such as for municipal drinking water, industrial water, or others (CDWR, 2016). Brackish water can be most economically desalinated on a large scale e.g., 1 mgd (or about 3,785 m³/d) including both capital and operating costs. However, there is no single desalination technology that is considered best for all uses. The selection of the most appropriate technology depends on the composition of the feedwater (seawater prior to desalination), the desired quality of the product water, and many other site-specific factors. Desalination technologies cannot produce water where there is none (US-OTA, 1988).

To produce quality freshwater with a sustainable platform, selecting seawater as a nominated feedwater for desalination becomes the right choice because seawater is an abundant source and not significantly influenced by seasons, it also may supply feedwater with stable quality without any significant fluctuation over the time. For this purpose, seawater reverse-osmosis (SWRO) is the most effective way to remove the salts and minerals by means of a fabricated membrane filtration system with the pore size less than 0.001 µm (or 1x10⁻⁶ mm) as in the ionic range, then reducing TDS concentration from 10,000-40,000 mg/L (brackish up to saline water) to 250-500 mg/L (freshwater).

There are three major components of a desalination plant such as pretreatment, high-pressure pump, and reverse-osmosis membrane filters. However, there are some item lists supporting the desalination plant as part of the system i.e., mechanicals, electrical, instrument, chemical, and others. To simplify the discussion, then focus on these three major components.

a. Pretreatment

In common practice, a pretreatment is intended to remove harmful suspended solids, remove oxidizers, and prevent precipitation in the desalination plant. The pretreatment prior to membrane filtration is extremely important and the nature and thoroughness of the pretreatment are, in many cases, determining the overall plant performance. The pretreatment configuration is more customized depending on the feedwater quality for example to reduce volatile organic compounds (VOCs), chlorine, and other contaminants by applying an activated carbon filter (ACF), to settle suspended solid by applying coagulant and flocculant, to increase solubility by applying pH adjuster, to retard crystallization by applying an anti-scaling agent, to remove dissolved organic solids prior to reverse-osmosis by applying ultrafiltration or nanofiltration,

and others (Wagner, 2001). Multi-media filter (MMF) consists of garnet, silica sand, and anthracite are also can used to reduce turbidity and light sediment materials.

b. High-Pressure Pump

Seawater is injected by the high-pressure pump into the modules of filter membranes to produce permeate water as product water and reject water (brine) as a by-product. The high-pressure pump is required to force feedwater across a semi-permeable filter membrane with a pressure of about 150 bars (1.5 MPa) depending on the feedwater quality, the higher the TDS value the higher pressure required. Carefulness in selecting the high-pressure pump capacity is very important to ensure no scaling and fouling issues on the membrane filters.

c. Membrane Filter

A membrane filter in a spiral wound element type is originally made exclusively for water desalination, but the very compact design and the low price made it to attractive to other industries. The cross section of the membrane module is shown in the following Figure 4 (Wagner, 2001). The membrane filters are grouped based on the pore size of the membrane namely microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse-osmosis (RO) in which their features shown in the following Figure 5. Microfiltration (MF) has a pore size range of about 0.03 to 10 μm and ultrafiltration (UF) membrane of about 0.002 to 0.1 μm are purely mechanical “fine-sieves” (CDWR, 2016). These fine sieves consist of porous, artificially created films, so-called membranes, with precisely defined pore diameters. The separating layers are applied to so-called carrier material. Polymers or ceramics are used as carrier materials.

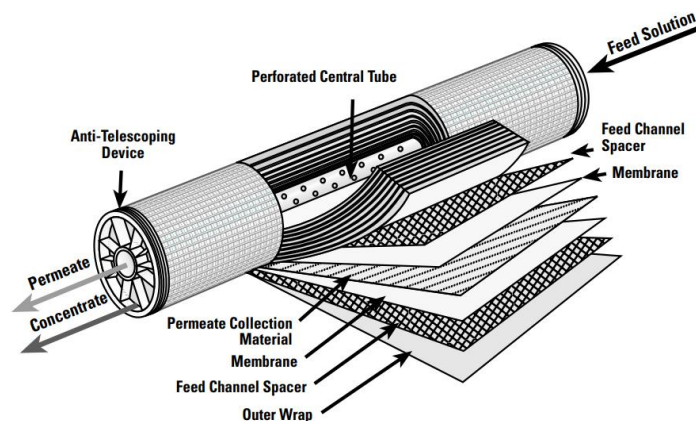


Figure 4 Cross-section of the membrane filter (Wagner, 2001)

Membrane filtration technologies are used for the widest variety of applications in the water treatment field, often in conjunction with classical processes. In nanofiltration (NF) with pores are near to or smaller than 0.01 μm and reverse-osmosis (RO) smaller than 0.001 μm , dense, diffusion-open membranes are used. In these processes, the separation process is performed by diffusion through the membrane. The driving force in all cases is the differential pressure. While differential pressures of up to 2 bar (200 kPa) are required for micro- and ultrafiltration, low-

pressure nanofiltration requires differential pressures of up to 8 bar (800 kPa) and reverse-osmosis up to 60 bar (6 MP) (Hydrogroup, 2022).

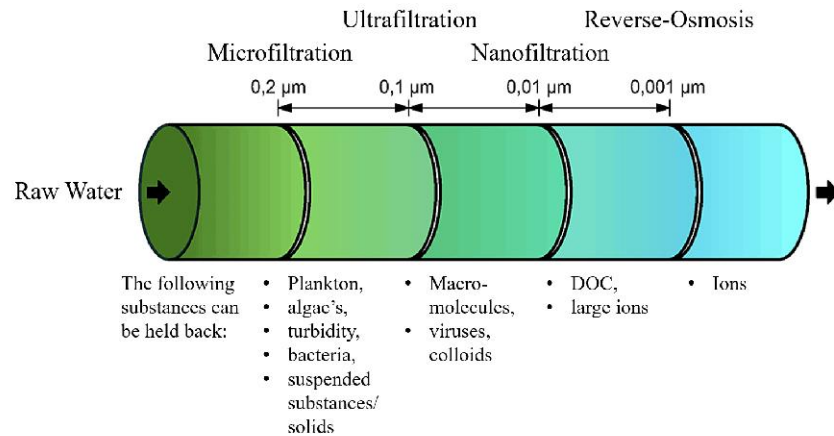


Figure 5. Membrane filters based on pore size (Hydrogroup, 2022).

d. Desalination Plant Configuration

The configuration of a desalination plant is customized depending on the feedwater quality and target of water product. Since PT AMNT intended to develop a new water source to support freshwater supply in Batu Hijau site wide for smelter and some major expansion projects, then the desalination becomes the best option for development. Referring to the seawater quality in the Batu Hijau site as mentioned in Table 4 and the target of the freshwater quality is according to the PERMENKES No. 32 Year 2017 regarding the water quality for sanitation hygiene with the water quality threshold i.e., pH 6.5 to 8.5, max. turbidity 25 NTU, max. total dissolved solids (TDS) 1,000 mg/L, max. fluoride (F) 1.5 mg/L, max. hardness (CaCO_3) 500 mg/L, max. manganese (Mn) 0.5 mg/L, max. nitrate (NO_3) 10 mg/L, max. nitrite (NO_2) 1 mg/L, max. cyanide (CN) 0.1 mg/L, and some heavy metal contents, then PT AMNT provides the conceptual block flow diagram of the desalination plant to overcome the salinity issue (see Figure 6).

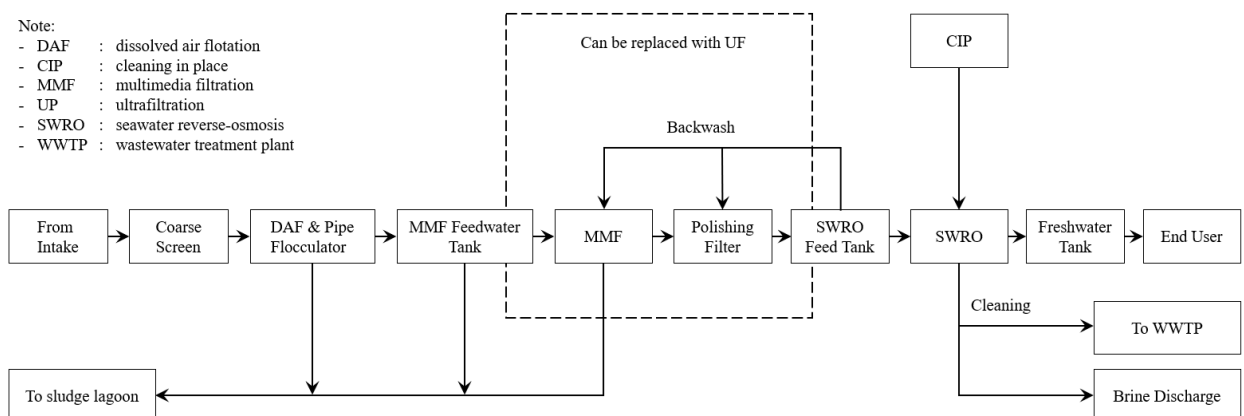


Figure 6. Block flow diagram of desalination plant

To handle the low quality of feedwater, a pretreatment either coarse screen, dissolved air flotation (DAF), multimedia filter (MMF), polishing filter, and others are dedicated to cleaning the seawater prior to the process in seawater reverse-osmosis (SWRO). The multi-media filter (MMF) and polishing filter can be replaced by ultrafiltration (UF). The use of the DAF, flocculator, and MMF lead to generating sludge, meanwhile, the SWRO may generate a by-product (brine water) and reject water to be discharged to wastewater treatment and/or brine discharge. The brine and reject water flowrate are double and triple the product water since the recovery of about 35 to 45% means the feedwater should be about 13,500 m³/d when the target of product water (freshwater) of about 4,500 m³/d.

Based on these analyses, theoretically, PT AMNT may convince to be able to produce the freshwater with the PERMENKES standard according to the conceptual block flow diagram above.

e. Future Challenges

The near future challenges in operating the desalination plant is since the plant is a customized process with its complexity in the feedwater parameters and desired target of product water, wide ranges on the technical and material specifications of fabricated filter membranes, its continuity of products, and technical support from manufacturer or supplier may lead to the reliability level of the whole desalination system to produce the freshwater in the long terms operations.

In terms of cost during 30 years operations, the capital expenses (CAPEX) to build a new desalination plant and its supporting infrastructures with life service of about 15 years, additional capital expenses in the 16th years for revitalization, and operating expenses (OPEX) per year to operate and maintain the plant (electric power, consumable materials, spare part replacement, etc.) when compared with the ordinary groundwater production wells, it takes ten to eighteen times higher. To date, the desalination technology is still expensive and more suitable to applied in for special requirements.

As known, the desalination plant is also requiring high electric power, so the sustainability and reliability of the power source become important to manage. Any backup power i.e., automatic generator set (genset) may help the continuity of desalination operations without any disruption when power outage.

The other challenge is brine water and/or reject water as by-product of the desalination plant that should be well managed in term of an environmental point of view due to having a high salts concentration (hypersaline) that may impact the marine ecosystem and marine structures besides producing the sludge or solid waste when doing replacement of the RO membranes periodically. For this purpose, an environmental impact assessment is required to address discharging brine water, outlet placement, and all downstream issues also its impact to the biological, chemical, and physical aspects mainly in marine biota, fishery, and other marine structures related to the corrosion issue.

CONCLUSION

Desalination technology is the best option to increase the freshwater production rate to fulfill the gap of water shortfall during construction and future smelter also additional process-water for new process expansion operations, power expansion, LNG terminal, and some new facilities. The availability of the seawater as an abundant and unlimited resource made production of desalination plant become secure and sustainable without influenced by seasons and poor of water quality. The plant may produce the freshwater of minimum 4,500-m³/d by design, nevertheless, it can be increased as per future requirements.

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