Preventing Unplanned Shutdown due to Injection Well Plugging with After Treatment Unit Integrated Membrane at Matindok CPP

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Abstract

Pertamina EP Pertamina EP Donggi Matindok Field realizes that sustainable development activities need to pay attention to environmental aspects, including efforts to reduce the load of water pollution. In the production process at Matindok Central Processing Plant (CPP), by-products are produced in 2 forms: solid sulphur and wastewater from the Biological Sulphur Recovery Unit (BSRU). Sulphur solids carried in wastewater can cause blockages known as plugging in injection wells and disrupt the production process. This study aims to reduce the water pollutants by integrating a nanofiltration membrane in the Bleed Water Treatment (BWT) to reduce the Total Dissolved Solid (TDS) content in wastewater after being processed in the After Treatment Unit (ATU). The experimental results showed a significant decrease in TDS values after nanofiltration membrane integration, from ≥14,000 mg/L to <4,000 mg/L. This program succeeded in reducing water pollution in 2023 by 272.68 tons of TDS.

Keywords: Elementary Sulphur Solid, Injection Well, Nanofiltration Membrane, TDS

1. Introduction

1.1 Introduce the Problem

Matindok Central Processing Plant (CPP) processes raw gas from gas wells into natural gas through several production processes. The process of removing gas impurities in Acid Gas Removal Unit (AGRU) produces emissions in the form of acid gas, which is further processed at Biological Sulphur Recovery Unit (BSRU) with the help of bacteria. The process that occurs at BSRU produces side products in the form of elementary sulphur solid and liquid waste known as produced water. Produced water is underground formation water carried away during the oil and gas production and exploration process. Due to long-term contact with hydrocarbons, produced water contains several chemical characteristics and hydrocarbon contents (Hasan, et al., 2018). The components of produced water depend on geographical conditions, where generally produced water is acidic and contains several types of minerals and ions. The chemical content,

Vol. 9, No. 02; 2024

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characteristic, and volume of produced water vary depending on the production facility, formation structure, tank type and length of the injection process. The main components in produced water consist of dissolved gas, dispersed and dissolved oil, dissolved minerals, chemical components and solids (Mansour, et al., 2022; Ersahin, et al., 2018). Produced water is produced from two processes in the oil and gas industry. The first is produced from a production process that is mixed with oil and gas. Second, water is injected into the deep well to lift oil to the surface (Al-Ghouti, et al., 2019).

In processing produced water, Matindok CPP initially have Bleed Water Treatment (BWT) which consist of Bioreactor R_2, Circulation Tank, Membrane Filter, Filtrate and Sulphur Dewatering. Produced water that has been processed at the BWT will then be injected into the advanced processing unit, namely the After Treatment Unit (ATU), which consists of Equalization, Neutralization, Oxidation, Flocculation-Coagulation, Sedimentation equipped with Filter Press, Sand Filter, Carbon Filter, and Filtrate. Produced water that has been processed in ATU will be stored in Produced Water Tank (PWT) to be injected into MLR-2ST injection well. However, a plugging event occurred at MLR-2ST injection well.

After further investigation, the plugging was caused by organic and inorganic compounds that are still carried and attached to the pipes and tanks forming elementary sulphur solids which clog the injection pipe and increase the injection pressure, resulting in a significant reduction in gas production. High elementary sulphur solid content has the potential to cause injection failure from the Produced Water Tank (PWT) to the injection well. Failure of the injection process and limited PWT capacity causing water accumulation on it can also disrupt the main production process which has the potential to cause an unplanned shutdown. Apart from that, plugging also causes production failure, in which there is failure in gas delivery and the potential for injection to exceed the quality standard threshold as stated in Minister of Environment and Forestry Regulation Number 19 Year 2010 concerning wastewater quality standards for oil and gas and geothermal businesses and/or activities.

Dissolved elementary sulphur solids that are still contained in liquid waste or produced water are recorded as Total Dissolved Solid (TDS) content which can cause plugging in injection wells. TDS is a collection of salts, metals, metalloids, and organic matter in water, which can give taste in water and provide source of cations and anions such as calcium, magnesium, potassium, sodium, carbonate, bicarbonate, nitrate, chloride, sulfate, and others. (Islam, et al., 2016; Rusydi, 2018; Wang, 2021). Specific ions with certain concentrations in TDS content can cause toxicological effects in water (Butler and Ford, 2017). Based on Minister of Environment and Forestry Regulation Number 19 Year 2010 concerning wastewater quality standards for oil and gas and geothermal businesses and/or activities, TDS threshold amount of produced water injected into injection well is 4,000 mg/L, so it is expected for gas company to reduce TDS below the threshold.

Several studies that have been carried out to overcome problems in the produced water injection process, include combining physics, chemistry and biological treatment with goals to reduce pollutant to environment are as follows.

Table 1. State of the Art

Author	Year	Research
Munirasu, S., Haija, M. A., & Banat, F.	2016	Wastewater purifying using reverse osmosis in Tehran refinery to remove TSS and TDS.
Dastgheib, S. A., Knutson, C., Yang, Y., & Salih, H. H.	2016	Reverse osmosis method in removing high TDS up to 49%.
Mulyanti, R., & Susanto, H.	2018	Nanofiltration membrane to remove COD 99,4% and remove dissolved colorizer 90-95%
Jiménez, S. M., Micó, M. M., Arnaldos, M., Medina, F., & Contreras, S.	2018	Combining system in produced water, such as filter, ion exchange, and reverse osmosis to achieve TDS, boron, and ammonia removal up to 95%, 80%, and 80%.
Abdel-Fatah, M. A.	2018	Comparing reverse osmosis, ultrafiltration membrane, and nanofiltration membrane, the result shows that nanofiltration works better to reduce COD.

In general, the steps taken to prevent plugging in injection wells are settling, coagulation/flocculation, flotation, centrifugal separation, filtration, ultrafiltration, and/or reverse osmosis to reduce the content of organic and inorganic compounds (Mansour, et al., 2022). Conventional processes cannot remove high salt levels in water, so technology-based steps using membranes are needed (Venzke, et al., 2018). Membrane is a selective barrier between two phases. Membrane can be thin or thick, homogeneous or heterogeneous in structure, active or passive separation depending on the pressure applied, and in the process there are differences of concentration or temperature. Membrane has the ability to separate components easily due to its physical and/or chemical property differences between the membrane and permeable components (Mulder, 1996). Furthermore, Mulder (1996) states that there are 3 types of membranes, namely:

1. Polymer membrane is divided into two types, namely open porous membranes which are applied in microfiltration and ultrafiltration separation, and non-porous membranes which are used in gas separation and pervaporation
2. Inorganic membrane is considered superior to polymer membrane because they have high thermal, chemical, and mechanical stability
3. Biological membrane or synthetic membrane have a more complicated structure because they suppose to carry out specific separations, such as changing multilamellar vesicles into unilamellar vesicles in lipids.

The use of membranes in wastewater treatment has long been used in the oil and gas refining industry for liquid separation or purification processes, because it has high efficiency and requires low costs. Nanofiltration membrane is used as the first step in the desalination process, because it is able to remove more than 95% of divalent ions and monovalent ions, as well as micro-sized compounds or materials and is able to remove dissolved salts effectively (Riley, et al., 2016; Kusworo, et al., 2018). Nanofiltration membrane has a combined working principle of ultrafiltration and reverse osmosis which can filter solids measuring 1 nm with a molecular weight of 300-500 Da. Nanofiltration membrane is able to separate inorganic salts and small organic molecules. Compared with reverse osmosis, nanofiltration membrane removes little monovalent ions, but effective in removing divalent ions and has a high flow rate (Mohammad, et al., 2015). Reverse osmosis and nanofiltration membrane have the basic principle of applying pressure and forcing flow into semipermeable membrane, so that it can pass through the membrane pores. Nanofiltration membrane is flexible in its arrangement and can be composed of several types of materials such as reverse osmosis membrane polymers such as cellulose acetate and polyamide polymers or other polymers that are resistant to chemicals. The ease of fabricating nanofiltration membrane can increase the use of membrane in various processes (Abdel-Fatah, 2018).

Pertamina EP Donggi Matindok Field made preventive action to anticipate future plugging at injection well by integrating After Treatment Unit (ATU) outlet with the membrane unit located in Bleed Water Treatment (BWT). Membrane unit on BWT uses a nanofiltration membrane which has the basic principle similar to reverse osmosis. Nanofiltration membrane works by filtering solids on the surface of the membrane, then the membrane will capture dissolved elementary sulphur particles that are less than 1 micron so that the dissolved elementary sulphur content in liquid waste can be reduced.

2. Method

2.1 Laboratory Analysis Resluts Before Membrane Integration

After Treatment Unit (ATU) outlet samples were taken consecutively from 27 February 2023 to 01 March 2023. The internal laboratory test results show that the produced water resulting from ATU process still has a high TDS content. The high TDS content in the produced water output from ATU indicates the high content of dissolved sulphur solids. These sulphur solids is what caused plugging in injection wells, which can disrupt the production process.

Table 2. Laboratory Analysis Results on After Treatment Unit (ATU) Outlets Before Membrane

Parameter	Unit	Laboratory Analysis Results		
		27 Feb 2023	28 Feb 2023	01 Mar 2023
TDS	mg/L	15,400	14,960	14,920

2.2 Fishbone Diagram

Fishbone Diagram (FD) or commonly referred to as a cause-and-effect diagram, Kaoru Ishikawa found FD as the root solution to a problem. FD can indicate the relationship between the problem that arises and the cause of the problem. By arranging step by step to study influencing factors, FD can make complex problems more systematic. A more specific analysis begins by analyzing the factors that most influence a process/situation, then followed by analyzing the most influential causes to find causes with medium, small and less influence, so that the main cause can be found and determined (Luo, et al., 2018). FD is able to visualize a mechanism with different processes through a line graph of the factors that influence an object (Yurin, et al., 2018). FD has 6 analysis variables, namely tools, people, processes, materials, environment, and management, which can analyze opportunities and consequences based on the risk of each variable (Dharma, et al., 2019). Based on the FD shown in Figure 1, the absence of a method for removing dissolved sulphur solids optimally has the potential to cause sulphur hardening which can cause plugging in injection wells. Existing waste processing facilities cannot separate sulphur solids from liquids, so the TDS content as a solid sulphur parameter is quite high which causes the accumulation of concentrated sulphur in the piping system.

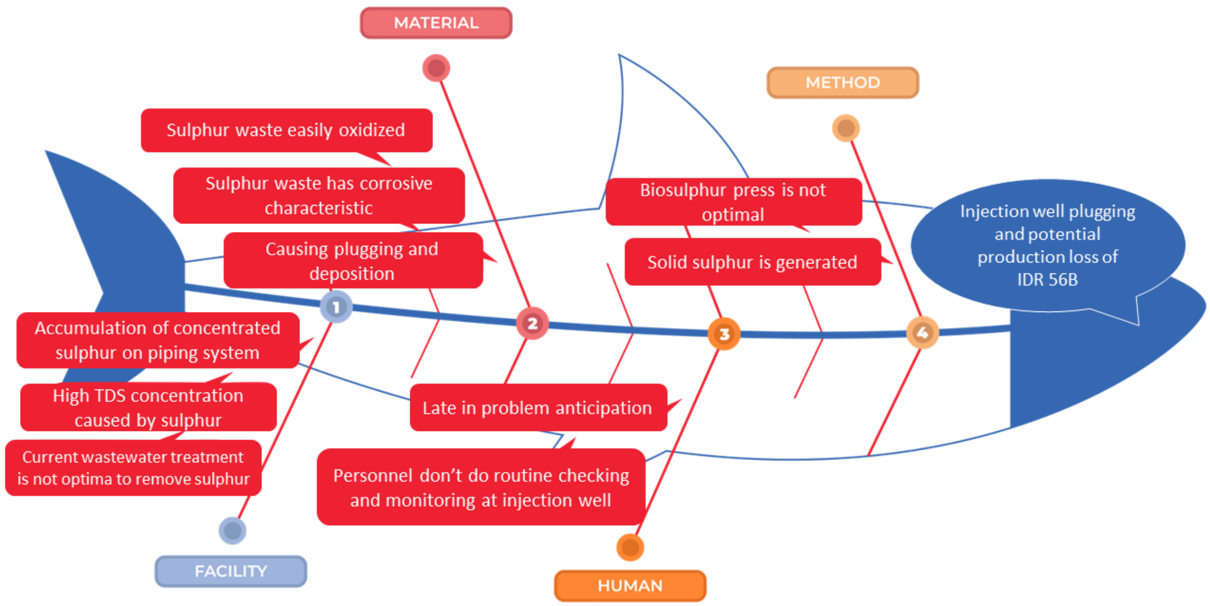

Figure 1. Fishbone Analysis of Potential Plugging at Injection Well

2.3 Failure Mode and Effects Analysis (FMEA)

As an effort to resolve the potential of future plugging event at injection well, an analysis is carried out using the Failure Mode and Effects Analysis (FMEA) method. FMEA is a systematic method for identifying and focusing on preventing technical, product, and process problems. Through FMEA analysis, evaluation and identification of potential failures are carried out at each stage of the process, so that improvements can be made to minimize the risk of failure, as well as reducing large costs, time efficiency, and ensuring product quality in the long term (Sharma and Srivastava, 2018; Wu, et al., 2021). FMEA determines failure risk priorities through the Risk Priority Number (RPN) which includes Occurance (O), Severity (S), and Detection (D) (RPN = O*S*D), shown in Table 3. The severity indicator shows the impact level of a particular failure, ranging from the mildest to the most serious impact. Occurrence shows the frequency of failures from rare to unavoidable failures. Meanwhile, detection is an indicator that shows the possibility of a failure with a large impact that was not previously detected, with indications of almost detected to undetected (Peeters, et al., 2018). Based on Table 3, it shows that the absence

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of optimal waste processing facilities to remove dissolved sulphur solids is the dominant factor that causing plugging event with the largest RPN percentage of 73%.

Table 3. Defining Failure Risk by RPN

ID	Kategori	Faktor Penyebab	S	O	D	RPN	% Relative	% Cumulative
A	Facility	The existing wastewater treatment facility can not separate solid sulphur from wastewater hence causing high TDS and accumulation of solid sulphur in piping system.	8	8	4	256	73	73
B	Material	Solid sulphur easily oxidized hence can be corrosive in piping system and forming deposition.	4	4	4	64	18	91
C	Method	Current biosulphur pressed is not optimal causing excessive solid sulphur accumulation in After Treatment Unit	4	4	2	32	9	100

2.1 Alternative Solution

Several methods can be used to minimize dissolved sulphur solids in produced water, such as acidification methods, adding filters to injection well, and application of membrane. Acidification method is carried out by injecting an acid solution into the formation at low pressure. When acid is injected, the acid solution will penetrate the formation pores and dissolve minerals and chemical components (Liu, et al., 2019). Zhang, et al (2020) stated that plugging can be overcome by a chemical acidification method using a super acid liquid with a high solubility level. However, this method is quite complicated, requires large costs, and can pollute the environment. On the other side, physical process by adding filters to injection wells is considered a relatively simple method, because it only uses porous media which is able to capture impurities in produced water (Al-Ghouti, et al., 2019). Filter media is able to separate dissolved solids from solutions optimally, however the filter media used is easily polluted so it needs further maintenance, produced water cannot have a high oil content, and requires continuous media replacement (Liu, et al., 2021). The method using a separation membrane is capable of producing high quality permeate, requires a small area, easy to operate, and required energy and costs that are relatively small. Belows on Table 4 is several ways that can be done to minimize the high levels of dissolved sulphur solids in produced water.

ISSN: 2456-3676

Table. 4 Alternative Solution

Alternative Solution	Cost	Duration	Operational	Materials	Risk
Integrating Membrane Nanofiltration with outlet of After Treatment Unit (ATU)	IDR 0	1 month	Integrating After Treatment Unit (ATU) output to nanofiltration membrane in Bleed Water Treatment (BWT).	No need to add new materials	Low
Acidizing System in Injection Well	IDR 100,000,000	1 month	Operation can be hard because of the use of HCl (high acidity)	Need to add new materials	Low
Filter Construction in Injection Well	IDR 100,000,000	1 year	High maintenance because the location of the filter is near injection well and high possibility of plugging.	Need to add new materials	Low

In the produced water treatment, there are several types of membranes made from polymer materials to inorganic materials, such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis membranes. Based on the quality of the effluent and the energy consumption, the membranes can be sorted: reverse osmosis > NF > UF > MF. However, at transmembrane operational pressure, a pressure of 5-200 kPa is required for MF and UF, and 7500 kPa for reverse osmosis membranes. Compared to reverse osmosis, nanofiltration membranes have good stability, so using nanofiltration membranes is the most efficient choice (Jiménez, et al., 2018; Guo, et al., 2020). Nanofiltration membranes work without requiring phase exchange and are able to separate inorganic multivalent salts and micro-sized organic molecules (< 10 μm) at low pressure, making nanofiltration membranes have a high level of selectivity at low cost compared to conventional separation methods (Oatley-Radcliffe, et al., 2017; Dickhout, et al., 2017). The integration of ATU outlet with the nanofiltration membrane on the BWT is expected to filter elementary sulphur solids measuring less than 1 micron, so that the TDS content in wastewater can be reduced. The decrease of elementary sulphur solid content can prevent plugging event at injection well.

Vol. 9, No. 02; 2024

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3. Results

3.1 Integration with Nanofiltration Membranes

Liquid waste flowing from Biological Sulphur Recovery Unit (BSRU) will enter the equalization pond to equalize the composition of the input bleed water before entering treatment unit. Next, the bleed water is flowed into a neutralization tank to neutralize the pH by adding HCl because the pH of the input bleed water is around 8-9. The pH neutralization process aims to optimize the oxidation process so that it maximally reduces the Chemical Oxygen Demand (COD) value, but still minimally oxidizes elemental sulphur. The neutral water enters the oxidation tank to remove color, odor, organic matter and COD value with the addition of H_2O_2. Then, the water will flow into the process tank for the coagulation and flocculation processes, to produce efficient solid-liquid separation in the water. The types of coagulants and flocculants used in process tanks are polyaluminium and polymer. In the coagulation process, small colloids suspended in water become unstable because the surface charge is reduced by one due to the addition of a coagulant with a different charge, so that the unstable particles gather and settle. To speed up the deposition process, polymer flocculants with long flexible chains are added after the catalyst coagulation process in the coagulation process. Polymer flocculants act as bridges that adsorb and connect various colloidal particles in water to form large solids that can be effectively removed through sedimentation. This process is called the flocculation process (Wei, et al., 2018). The results of the flocculation process will enter the sedimentation tank to separate the solid sulphur deposits from the liquid phase due to the difference in density.

The sulphur deposits will be converted into dry sludge, while the water produced will be flowed to the filtration process through sand filter media and the adsorption process through activated carbon filter media to remove remaining Total Suspended Solid (TSS), COD, heavy metals, phenol, ammonia, impurities. organics, and sulfides. Sand filter functions as a fixed media bioreactor that is resistant to changes in pH, surfactants and metals. In wastewater treatment, sand filter is able to remove turbidity, suspended solids, and pathogens in water (Verma, et al., 2017). The large adsorption capacity, pore structure, and differences in oxygen-functional groups on the surface of the material make activated carbon an adsorbent that frequently used to remove contaminants in wastewater (Mousavi, et al., 2021).

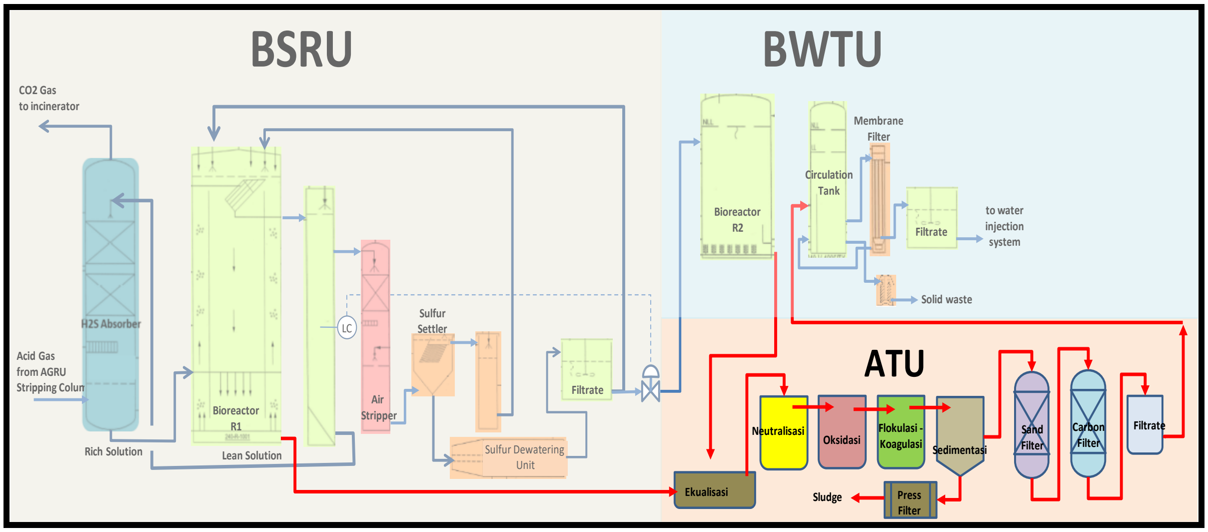


Figure 2. Integration of Nanofiltration Membranes in Bleed Water Treatment (BWT) with After Treatment Unit (ATU) Outlets

Wastewater that has passed through the carbon filter will enter the circulation tank to adjust the water flow rate which will be passed into the nanofiltration membrane. Nanofiltration has membrane pores measuring 0.5-2.0 nm and works at a pressure between reverse osmosis and ultrafiltration membranes, which is able to provide effective separation results and low energy consumption. Based on the electrostatic repulsion effect and the steric hydrant effect, nanofiltration membranes can separate mono/multivalent salts and organic molecules of different sizes (Ji, et al., 2017). Separation of solids in nanofiltration membrane is based on differences in particle size and charge effects of ionic components. Components with high molecular weight are separated by sieving system.

The separation method by sieving is a method commonly used to separate large (macro) particles or particles that have a large molecular weight (Biazzi, et al., 2022). In this case, elementary sulphur solids which have a large molecular weight can be separated from produced water during filtration phase with sieving method. While elementary sulphur solids with a small molecular weight (micro) cannot be separated using the sieving method, micro elementary sulphur solids with size of 1 nm are separated using nanofiltration membrane. Low weight molecules and ionic molecules will be separated by charge effects and solution diffusion mechanisms (Mulyanti and Susanto, 2018). Nanofiltration has a function that is almost similar to reverse osmosis, the dominant difference is in the pressure requirement. Chuntanalerg (2019) states that nanofiltration membranes have micro pores of 0.2-2 nm with an MWCO of 200-1000 Da. Based on this, elementary sulphur solids measuring ≤ 1 nm can be separated using a nanofiltration membrane because it has a pore size that can filter micro-sized elementary sulphur solid, hence TDS removal content in produced water can be reduced significantly. Produced water that has passed through the nanofiltration membrane is then passed into the Produce Water Tank (PWT) to be further injected into the MLR-2ST injection well.

Vol. 9, No. 02; 2024

ISSN: 2456-3676

3.2 Laboratory Analysis Results After Membrane Integration

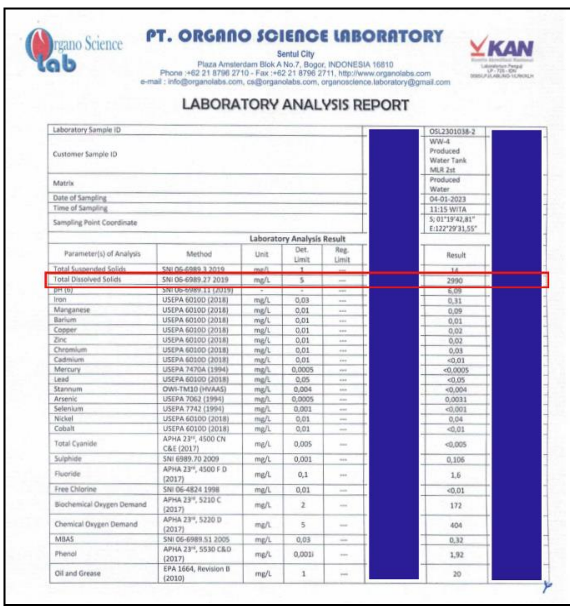
External laboratory analysis carried out after integrating the After Treatment Unit (ATU) outlet with the nanofiltration membrane at the Bleed Water Treatment (BWT) on April 1 2023 after the membrane integration was completed. Apart from that, external laboratory analysis was also carried out again on October 1 2023 as a form of environmental compliance by the Company in the 2nd semester of 2023. Laboratory test samples were taken at the Produce Water Tank, which is the tank where produced water is collected and has passed through the nanofiltration membrane on Bleed Water Treatment (BWT).

Table. 5 Laboratory Analysis Result After Nanofiltration Membrane Integration

Parameter	Unit	Treshold*	Lab Test Result	
			01 April 2023	**01 Oktober 2023**
TDS	mg/L	4,000	2,990	1,370

*Ministry of Environment and Forestry Regulation Number 19 Year 2010

External laboratory test results show a significant decrease in TDS values. The average decrease in TDS value after produced water passes through the nanofiltration membrane reaches 80% compared to produced water that does not pass through the nanofiltration membrane on BWT. Reducing TDS levels in produced water before injection can prevent plugging at injection well. Apart from that, with the integration of the After Treatment Unit (ATU) outlet with the nanofiltration membrane on Bleed Water Treatment (BWT), the company no longer have to pay for injection well maintenance service contracts, reduce after treatment rental costs, and there are no wastewater spills due to over-carrying of pollutants, as well as reducing preventive cleaning maintenance from once per month to once every 3 months.



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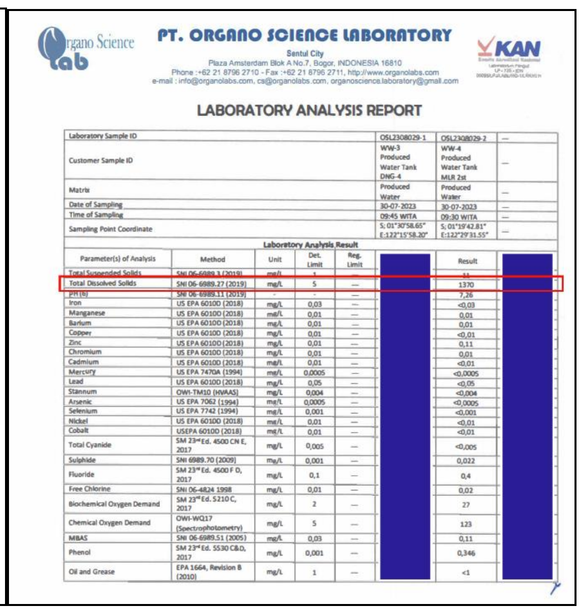
LABORATORY ANALYSIS REPORT

Laboratory Sample ID					[redacted]	OSL2301038-2	[redacted]
Customer Sample ID						WW-4 Produced Water Tank MLR 2st	
Matrix						Produced Water	
Date of Sampling						04-01-2023	
Time of Sampling						11:15 WITA	
Sampling Point Coordinate						S; 01°19'42,81" E:122°29'31,55"	
Laboratory Analysis Result							
Parameter(s) of Analysis	Method	Unit	Det. Limit	Reg. Limit		Result	
Total Suspended Solids	SNI 06-6989.3 2019	mg/L	1	---		14	
Total Dissolved Solids	SNI 06-6989.27 2019	mg/L	5	—		2990	
pH (6)	SNI 06-6989.11 (2019)	-	-	---		6,09	
Iron	USEPA 6010D (2018)	mg/L	0,03	---		0,31	
Manganese	USEPA 6010D (2018)	mg/L	0,01	---		0,09	
Barium	USEPA 6010D (2018)	mg/L	0,01	---		0,01	
Copper	USEPA 6010D (2018)	mg/L	0,01	---		0,02	
Zinc	USEPA 6010D (2018)	mg/L	0,01	---		0,02	
Chromium	USEPA 6010D (2018)	mg/L	0,01	---		0,03	
Cadmium	USEPA 6010D (2018)	mg/L	0,01	---		<0,01	
Mercury	USEPA 7470A (1994)	mg/L	0,0005	---		<0,0005	
Lead	USEPA 6010D (2018)	mg/L	0,05	---		<0,05	
Stannum	OWI-TM10 (HVAAS)	mg/L	0,004	---		<0,004	
Arsenic	USEPA 7062 (1994)	mg/L	0,0005	---		0,0031	
Selenium	USEPA 7742 (1994)	mg/L	0,001	---		<0,001	
Nickel	USEPA 6010D (2018)	mg/L	0,01	---		0,04	
Cobalt	USEPA 6010D (2018)	mg/L	0,01	---		<0,01	
Total Cyanide	APHA 23rd, 4500 CN C&E (2017)	mg/L	0,005	---		<0,005	
Sulphide	SNI 6989.70 2009	mg/L	0,001	---		0,106	
Fluoride	APHA 23rd, 4500 F D (2017)	mg/L	0,1	---		1,6	
Free Chlorine	SNI 06-4824 1998	mg/L	0,01	---		<0,01	
Biochemical Oxygen Demand	APHA 23rd, 5210 C (2017)	mg/L	2	---		172	
Chemical Oxygen Demand	APHA 23rd, 5220 D (2017)	mg/L	5	---		404	
MBAS	SNI 06-6989.51 2005	mg/L	0,03	---		0,32	
Phenol	APHA 23rd, 5530 C&D (2017)	mg/L	0,001i	---		1,92	
Oil and Grease	EPA 1664, Revision B (2010)	mg/L	1	---		20	



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LABORATORY ANALYSIS REPORT

Laboratory Sample ID					OSL2308029-1	OSL2308029-2	—
Customer Sample ID					WW-3 Produced Water Tank DNG-4	WW-4 Produced Water Tank MLR 2st	—
Matrix					Produced Water	Produced Water	—
Date of Sampling					30-07-2023	30-07-2023	—
Time of Sampling					09:45 WITA	09:30 WITA	—
Sampling Point Coordinate					S; 01°30'58.65" E:122°15'58.20"	S; 01°19'42.81" E:122°29'31.55"	—
Laboratory Analysis Result							
Parameter(s) of Analysis	Method	Unit	Det. Limit	Reg. Limit	[redacted]	Result	[redacted]
Total Suspended Solids	SNI 06-6989.3 (2019)	mg/L	1	—		11	
Total Dissolved Solids	SNI 06-6989.27 (2019)	mg/L	5	—		1370	
pH (6)	SNI 06-6989.11 (2019)	-	-	—		7,26	
Iron	US EPA 6010D (2018)	mg/L	0,03	—		<0,03	
Manganese	US EPA 6010D (2018)	mg/L	0,01	—		0,01	
Barium	US EPA 6010D (2018)	mg/L	0,01	—		0,01	
Copper	US EPA 6010D (2018)	mg/L	0,01	—		<0,01	
Zinc	US EPA 6010D (2018)	mg/L	0,01	—		0,11	
Chromium	US EPA 6010D (2018)	mg/L	0,01	—		0,01	
Cadmium	US EPA 6010D (2018)	mg/L	0,01	—		<0,01	
Mercury	US EPA 7470A (1994)	mg/L	0,0005	—		<0,0005	
Lead	US EPA 6010D (2018)	mg/L	0,05	—		<0,05	
Stannum	OWI-TM10 (HVAAS)	mg/L	0,004	—		<0,004	
Arsenic	US EPA 7062 (1994)	mg/L	0,0005	—		<0,0005	
Selenium	US EPA 7742 (1994)	mg/L	0,001	—		<0,001	
Nickel	US EPA 6010D (2018)	mg/L	0,01	—		<0,01	
Cobalt	USEPA 6010D (2018)	mg/L	0,01	—		<0,01	
Total Cyanide	SM 23rd Ed. 4500 CN E, 2017	mg/L	0,005	—		<0,005	
Sulphide	SNI 6989.70 (2009)	mg/L	0,001	—		0,022	
Fluoride	SM 23rd Ed. 4500 F D, 2017	mg/L	0,1	—		0,4	
Free Chlorine	SNI 06-4824 1998	mg/L	0,01	—		0,02	
Biochemical Oxygen Demand	SM 23rd Ed. 5210 C, 2017	mg/L	2	—		27	
Chemical Oxygen Demand	OWI-WQ17 (Spectrophotometry)	mg/L	5	—		123	
MBAS	SNI 06-6989.51 (2005)	mg/L	0,03	—		0,11	
Phenol	SM 23rd Ed. 5530 C&D, 2017	mg/L	0,001	—		0,346	
Oil and Grease	EPA 1664, Revision B (2010)	mg/L	1	—		<1	

Figure 3. External Laboratory Test Results Report

3.3 Reduction of Water Pollution Load

Injection flow in Matindok CPP 2023 = 21,972.60 m3/year

TDS Concentration Rate Before Installation = 15,400 mg/L

TDS Concentration Rate After Installation = 2,990 mg/L

Water pollution load reduced (ton/year)

= Injection Flow (m^3/year) x concentration reduced (mg/L) x 1,000L/m^3 x kg/1,000 mg

= 21,972.60 m^3/year x (15,400 mg/L – 2,990 mg/L) x 1,000L/m^3 x kg/1,000 mg

= 21,972.60 m^3/year x 12,410 mg/L x 1,000 L/m^3 x kg/10^6 mg

= 272,679.96 kg TDS/year

= 272.68 tons TDS/year

4. Conclusions

The application of nanofiltration membranes on Bleed Water Treatment integrated with outfall in After Treatment Unit makes a significant difference in reducing elementary sulphur solids contained in produced water, making nanofiltration membranes an effective solution in preventing plugging in injection wells. The experimental results showed a significant decrease in TDS values after nanofiltration membrane integration, from initially ≥14,000 mg/L to <4,000 mg/L. This program succeeded in reducing water pollution estimated in 2023 by 272.68 tons of TDS.

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