

# **Pengaruh Penambahan NaCl Konsentrasi 4% terhadap Sifat-Sifat Poliamina Lumpur Berbasis Air Berkinerja Tinggi pada Skala Laboratorium**

## **The Effect of 4% NaCl Concentrations Addition on the Properties of High Performance Water-Based Mud Polyamine on Laboratory Scale**

Agustina Prihantini<sup>(1,a)\*</sup>, Agung Setiawan<sup>(1)</sup>, Vivi Alifiah<sup>(1)</sup>

<sup>(1)</sup>Prodi D3 Perminyakan, Institut Teknologi Petroleum Balongan, Indramayu, Indonesia, 45216  
Email:<sup>(a\*)</sup> aprihantini89@gmail.com

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**Abstract.** Drilling mud is used as a fluid that plays a role in achieving the success of a drilling program. Failure to control the physical properties of the drilling mud will result in its failure. High Performance Water Based Mud (HPWBM) mud systems different with water base mud (WBM) conventional Which where is HPWBM can act like oil base mud (OBM) in matter lubrication and resistance to solid contamination. NaCl contamination causes stability drilling mud decreased so that the mud's ability drilling. This research aims to determine the effect of NaCl addition on the properties of High Performance Water Base Mud (HPWBM) Polyamine on a laboratory scale. This research was conducted at the BPPMGB Lemigas Laboratory, an institution that plays an important role in the development of oil and gas technology. This research evaluated the effect of 3%, 4%, and 5% NaCl contamination on the properties of Polyamine HPWBM mud. The results showed that the addition of NaCl changed the physical and rheological properties of the mud. Under BHR conditions, 3% NaCl gave the results closest to specifications, while under AHR conditions, 4% NaCl showed the best performance. Increasing the NaCl concentration increased the viscosity and stability against swelling clay, but also increased the potential for corrosion due to changes in the chemical properties of the drilling fluid.

**Keywords:** High Performance Water Base Mud, NaCl Contamination Sludge, Polyamine, Physical Properties of NaCl Sludge, Sludge Test.

**Abstrak.** Penggunaan lumpur pengeboran adalah sebagai fluida yang berperan untuk mencapai keberhasilan suatu program pengeboran. Kesalahan dalam mengontrol sifat-sifat fisik lumpur pengeboran akan menyebabkan kegagalan dari fungsi lumpur. Sistem lumpur high performance water base mud (HPWBM) berbeda dengan water base mud (WBM) konvensional yang mana HPWBM dapat bertindak seperti oil base mud (OBM) dalam hal pelumasan dan ketahanan terhadap kontaminasi padatan. Kontaminasi NaCl menyebabkan stabilitas lumpur pengeboran mengalami penurunan sehingga kemampuan lumpur pengeboran berkurang. Penelitian ini bertujuan untuk menentukan pengaruh penambahan NaCl terhadap properti High Performance Water Base Mud (HPWBM) Polyamine pada skala laboratorium. Penelitian ini dilaksanakan di Laboratorium BPPMGB Lemigas, yang merupakan sebuah lembaga yang berperan penting dalam pengembangan teknologi perminyakan dan gas bumi. Penelitian ini mengevaluasi pengaruh kontaminasi NaCl 3%, 4%, dan 5% terhadap sifat lumpur HPWBM Polyamine. Hasil menunjukkan bahwa penambahan NaCl mengubah sifat fisik dan reologi lumpur. Pada kondisi BHR, NaCl 3% memberikan hasil paling mendekati spesifikasi, sedangkan pada kondisi AHR, NaCl 4% menunjukkan performa terbaik. Peningkatan konsentrasi NaCl meningkatkan viskositas dan stabilitas terhadap swelling clay, namun juga meningkatkan potensi korosi akibat perubahan sifat kimia fluida pemboran.

**Katakunci:** High Performance Water Base Mud, Lumpur Kontaminasi NaCl, Polyamine, Sifat Fisik Lumpur NaCl, Uji Lumpur

## INTRODUCTION

The advancement of drilling technology is very beneficial and supports the oil and gas industry [1]. especially with the current conditions where high demand for oil and gas causes the search for reserves in deep reservoirs and is very challenging [2].

Drilling fluid plays a crucial role in the success of drilling operations. Its primary function is to lift cuttings to the surface, cool and lubricate the drill bit, mitigate formation pressure, and act as a filter cake. Mud that is not suited to formation conditions will cause well problems, including pipe sticking, loss of circulation, and wellbore instability, which can result in unproductive time and increased operational costs [3]. This is the reason that designing drilling fluid well will be able to provide solutions to overcome challenges in maintaining the desired rheological properties and can save operational costs in drilling by 5-15% [2][1].

Classification of drilling mud includes other types such as Water-based Fluids, Oil-based Fluids and Pneumatic Fluids [11]. Water-based mud drilling fluid is a type of mud that is more commonly used than oil-based mud drilling fluid. The use of water-based mud is due to its lower environmental impact during drilling operations, ease of handling, relatively lower costs and effectiveness [4]. However, the use of water-based mud also causes several problems, such as formation damage and filtration losses that reduce drilling efficiency[5]. Apparent and plastic viscosity are fundamental rheological characteristics of drilling fluids. Therefore, continuous monitoring of this rheology is necessary during drilling operations. Furthermore, temperature and salinity are major factors affecting the stability of water-based muds. The rheology of water-based muds is controlled by adding montmorillonite, also known as bentonite, which provides viscosity, gel strength, and fluid loss control [4].

The chemical properties of drilling mud are related to the chemical content of its particles. These chemical properties significantly determine the mud's function because the mud's properties can change depending on the chemical effects of the particles. These chemical changes can lead to difficulties in mud control and treatment. The chemical properties of drilling mud include solids, Pf and Mf, total hardness, alkalinity, salinity, and pH [6]. The physical properties of water-based mud include mud weight, flow properties (rheology), low-velocity settling point (LSYP), filtration, and mud cake. The methods used to test filtration loss are API Filter Press and HPHT. A good and desired mud cake is one that is able to cover the well wall so that it can prevent fluid from escaping into the formation and prevent leakage in the event of vibration [7].

NaCl is a widely available and readily available alternative that can replace KCl in inhibiting clay. The addition of polyamine, which acts as a shale inhibitor, will improve the inhibition properties of the mud [8][3]. This system is called high-performance water-based mud or HPWBM. High Performance Water Based Mud (HPWBM) is designed for drilling complex intervals, where its performance is almost equal to that of oil-based mud (OBM) drilling and also in producing gauge holes [9][10][11]. The results of the field-scale testing were highly successful compared to conventional fluid systems and methodologies. Drilling time for the well was faster than scheduled and 20% below budget. The HPWBM system saved more than 5% of the total well cost and was 16% cheaper than conventional fluid systems [11]. In research at Pertamina Hulu Mahakam, HPWBM with NaCl has been proven successful as an alternative mud system in offshore fields. During drilling activities, HPWBM with NaCl acts well as a inhibitor, so that integrated cuttings can be observed on the shale shaker and there are no sticky cuttings [8].

NaCl contamination can reduce the stability of drilling mud, so research on the influence of NaCl is important to understand chemical interactions in mud systems. The aim of this research is to determine the rheology of HPWBM mud with the addition of 3%, 4%, and 5% NaCl, then compare the properties of the mud at basic and basic conditions + 3%, 4%, and 5% NaCl, and determine the effect of adding NaCl contamination to the HPWBM mud system.

## **RESEARCH METHODOLOGY**

This research was conducted to determine the effect of NaCl addition on the properties of high performance water based mud polyamine. The method used in this research is quantitative, which begins with a literature research by reading relevant references and previous researchers to strengthen the theoretical basis.

The data collected includes laboratory equipment data used to make and test drilling mud, base material data, and additive data. The tools used in this research include a mixer used to make/mix mud materials whose physical properties will be measured. A pH meter to measure the degree of acidity (pH) of an environment, whether the solution is classified as acidic or basic. A pressurized fluid density balance measures the specific gravity of mud. A rheometer to measure mud properties. An API filter press to determine filtration loss and mud cake. A roll oven ofi test for heating and rolling simultaneously or separately. An aging cell to test the stability and changes in the properties of drilling fluids (mud) at high temperatures and pressures, and a hot plate magnetic stirrer to mix a substance with another substance to make it homogeneous. MBT (Methylene Blue Test) filter papers serve as a medium for dripping a mixture of mud samples and methylene blue solutions during the titration process. The additives used in the test include Bentonite, XCD Polymer, Polyamine, NaCl, Barite, Gilsonite, Driscal-D, Caustic soda (NaOH), Calcium Carbonate (CaCO<sub>3</sub>), Freakseal Fine, Biocide, Dristemp<sup>TM</sup>, Methylene Blue Solution, H<sub>2</sub>SO<sub>4</sub> 5N, H<sub>2</sub>O<sub>2</sub> 3%.

The NaCl concentration to be used for the research is determined. In this research, NaCl concentrations of 3%, 4%, and 5% were used. The next step is to make High Performance Water Base Mud (HPWBM) for the base mud and base mud added with NaCl at concentrations of 3%, 4%, and 5%. Next, the mud used for testing is prepared, followed by physical and rheological testing. The results of the tests are then compared to determine the desired NaCl concentration and the effect of NaCl addition on the drilling mud.

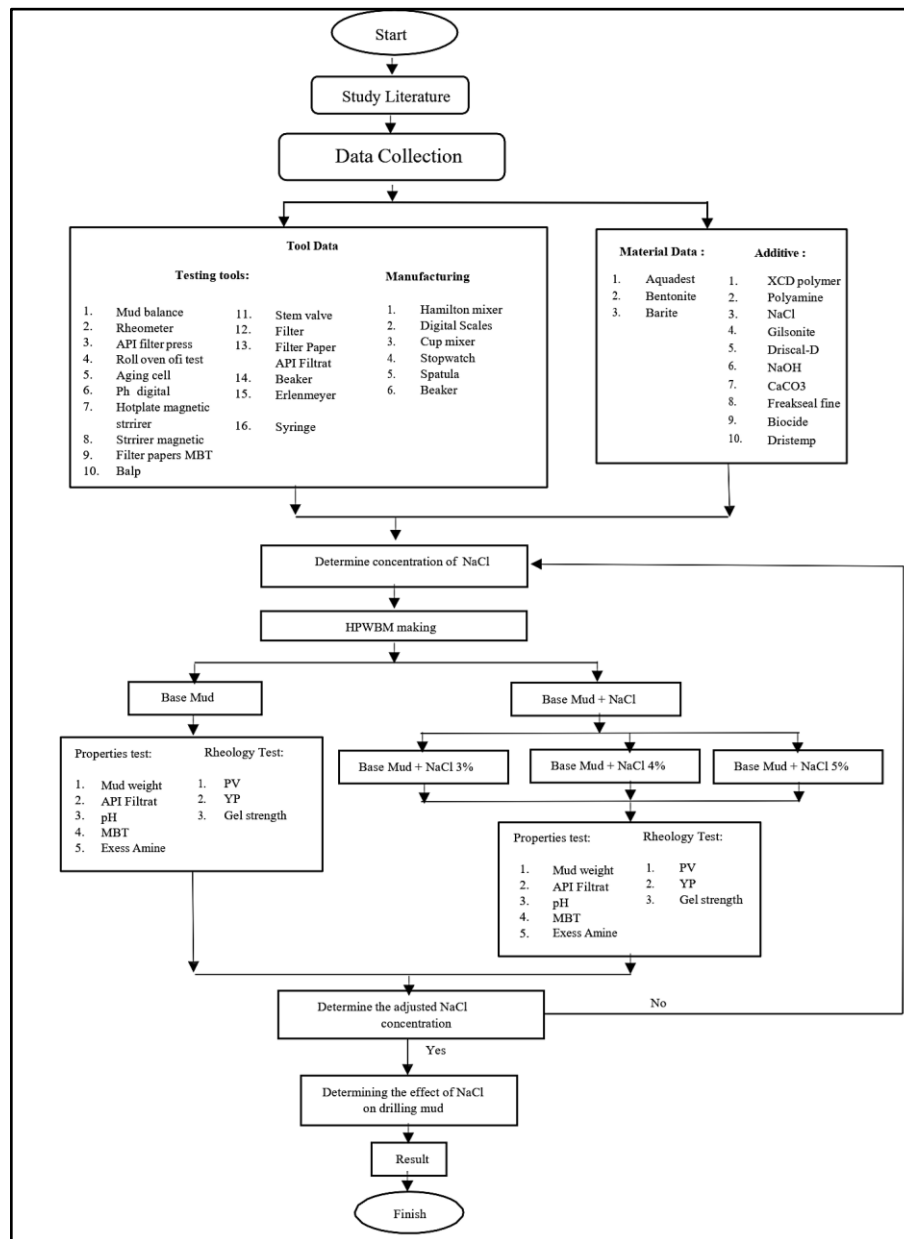


Figure 1. Research Flow Diagram

## RESULT AND DISCUSSION

This research was conducted in the BPPMGB Lemigas laboratory, South Jakarta. BPPMGB LEMIGAS (Center for Oil and Gas Testing) operates on a national scale under the Indonesian Ministry of Energy and Mineral Resources, but its services have international standards and accreditation. Researchers were allowed to formulate and test drilling mud based on the mud specifications in the BPPMGB Lemigas Laboratory as a reference. The determination of the NaCl variation used in the research was based on the equation of NaCl mass equals the percentage of NaCl multiplied by the volume of water. In this research, NaCl was used in variations of 3%, 4%, and 5%. To determine the mass of NaCl used, multiply the percentages of 3%, 4%, and 5% NaCl by the volume of water. Thus, the masses used were 8.05 grams, 10.73 grams, and 13.41 grams, respectively.

### HPWBM-Polyamine Sludge

In this research, the researcher makes mud with predetermined specifications.

**Table 1. HPWBM NaCl Polyamine Specification Data**

NO	Mud Properties	Original AHR (After Hot Rolling)	
		Spec	
1	MW (SG)	1.60 0.01	
2	Rheology @150F	600 rpm	Record
		300 rpm	Record
		200 rpm	Record
		100 rpm	Record
		6 rpm	Record
		3 rpm	Record
3	PV ( <i>Plastic Viscosity</i> ), cP	ALAP, < 45	
4	YP ( <i>Yield Point</i> ), lbs/100ft <sup>2</sup>	20-35	
5	LSR YP, lbs/100ft <sup>2</sup>	10-May	
6	Gel Strength 10 <i>sec</i> , lbs/100ft <sup>2</sup>	12-Jul	
7	Gel Strength 10 <i>mnt</i> , lbs/100ft <sup>2</sup>	28-Oct	
8	Filtrate API (100 psi), ml/30 min	<4	
9	HPHT @ 350 F, 500 psi	<12	
10	pH	9,5-11,0	
11	MBT, ppb	< 5	
12	POLYAMINE	1,7 – 2,0	

From the specification data as a reference in the manufacture of drilling mud, the researcher began to make HPWBM mud with base and base formulations +NaCl3%, NaCl 4% and NaCl 5%.

**Table 2. HPWBM NaCl Polyamine Formulation Data**

Products	Mixing order	Mixing time, min	Base	Base + NaCl	Base + NaCl	Base + NaCl
			HPWBM – Polyamine	3 % HPWBM – Polyamine	4% HPWBM Polyamine	5% HPWBM Polyamine
			Berat (g)	Berat (g)	Berat (g)	Berat (g)
Freshwater	1		268,19	265,23	264,21	264,21
NaCl	2	1	0,00	8,05	10,82	13,41
NaOH	3	1	3,00	3,00	3,00	3,00
BIOCIDE	4	1	0,25	0,25	0,25	0,25
Bentonite	5	3	5,00	5,00	5,00	5,00
Fracseal Fine	6	3	3,00	3,00	3,00	3,00
CaCO3 M	7	3	10,00	10,00	10,00	10,00
GILSONITE HT	8	3	6,00	6,00	6,00	6,00
Barite	9	3	225,00	225,00	225,00	225,00
Dristemp	10	5	3,50	3,50	3,50	3,50
Driscal -D	11	5	4,00	4,00	4,00	4,00
XCD Polymer	12	6	2,25	2,25	2,25	2,25
Polyamine	13	3	7,00	7,00	7,00	7,00

In the testing and calculation of HPWBM Polyamine sludge, it was tested under the condition of adding a few percent NaCl starting from the base without the addition of contaminants and the addition of 3%, 4% and 5% of NaCl contaminants, tested in 2 conditions, namely BHR (Before Hot 30 Rolling) and AHR (After Hot Rolling) at 350 °F or at a depth of 18,000 ft.

### Mud Density

This result was obtained from the analysis of the sludge weight using the pressurized mud balance tool and on the addition of NaCl 3%, 4% and 5%.

**Table 3. Density Measurement Results**

Base	NaCl 3%	NaCl 4%	NaCl 5%	Ket
1.15	1.56	1.58	no testing	Sg
9.58	13	13.2	no testing	ppg

From **Table 3**. The above results show that NaCl does not affect the specific gravity of drilling sludge. According to API RP 13B-1 and ISO 10414 standards, rheometer dial readings are generally performed at six speeds, namely 600, 300, 200, 100, 6, and 3 rpm. Each test speed has a different function. Readings at 600 and 300 RPM are used to calculate the Plastic Viscosity (PV) and Yield Point (YP), which describe the influence of dispersed solids and the tensile forces between particles in the sludge.

**Table 4. Rheology Measurement Results**

Properties	BHR				AHR			
	Base	NaCl 3%	NaCl 4%	NaCl 5%	Base	NaCl 3%	NaCl 4%	NaCl 5%
600 rpm	275	220	292	OS	204	142	144	105
300 rpm	213	197	236	259	144	89	95	69
200 rpm	163	162	203	225	113	68	71	51
100 rpm	125	119	152	178	75	43	44	27
6 rpm	46	29	39	52	18	5	4	2
3 rpm	37	19	26	37	14	3	3	1

Based on **Table 4**, the condition of BHR NaCl greatly affects the value of rheology where the higher the percentage of NaCl, the higher the rheology value.

### Plastic Viscosity

In this test, it was tested in the condition of adding a few percent of NaCl starting from the base without the addition of contaminants and the addition of 3%, 4% and 5% of NaCl contaminants, tested in 2 states, namely BHR (Before Hot Rolling) and AHR (After Hot Rolling).

**Table 5. PV Measurement Results**

	Base (cP)	NaCl 3% (cP)	NaCl 4% (cP)	NaCl 5% (cP)
BHR	6	23	56	No Testing
AHR	60	53	49	36

From **Table 5**, it shows that only 3% NaCl sludge enters the specification under the AHR condition, and no one enters the specification at AHR condition.

**Yield Point**

**Table 6. Yield Point Measurement Results**

	Base (lbs/100ft <sup>2</sup> )	NaCl 3% (lbs/100ft <sup>2</sup> )	NaCl 4% (lbs/100ft <sup>2</sup> )	NaCl 5% (lbs/100ft <sup>2</sup> )
BHR	151	174	180	No Testing
AHR	84	36	46	33

From **Table 6** it shows that no one has entered the existing specification yet.

**Low Share Rate Yield Point (LSRYP)**

**Table 7. LSRYP Measurement Results**

	Base (lbs/100ft <sup>2</sup> )	NaCl 3% (lbs/100ft <sup>2</sup> )	NaCl 4% (lbs/100ft <sup>2</sup> )	NaCl 5% (lbs/100ft <sup>2</sup> )
BHR	28	9	13	22
AHR	10	1	2	0

From **Table 7**, it shows that it enters the specification only at 3% NaCl sludge under the BHR condition, and at the AHR condition that enters the base sludge specification only.

**Gel Strength**

Gel strength indicates the ability of mud to hold or float drill chips when not in the drilling process, which is the formation of solids because of the tensile force of attraction to the clay plates if left still. For standardization, it is necessary to report gel strength twice, at 10 minutes and 30 minutes after the sludge is stirred.

**Table 8. Gel Strength 10 sec Measurement Results**

	Base (lbs/100ft <sup>2</sup> )	NaCl 3% (lbs/100ft <sup>2</sup> )	NaCl 4% (lbs/100ft <sup>2</sup> )	NaCl 5% (lbs/100ft <sup>2</sup> )
BHR	30	11	16	No Testing
AHR	11	1	1	1

From **Table 8**, it shows that it enters the specification only in 3% NaCl sludge in the BHR condition, and in the AHR condition that enters the base sludge specification only.

**Table 9. Gel Strength 10 min Measurement Results**

	Base (lbs/100ft <sup>2</sup> )	NaCl 3% (lbs/100ft <sup>2</sup> )	NaCl 4% (lbs/100ft <sup>2</sup> )	NaCl 5% (lbs/100ft <sup>2</sup> )
BHR	42	20	20	No Testing
AHR	6	2	3	2

From **Table 9**, it shows that those who enter the specification are in 3% NaCl sludge and 4% NaCl in the BHR condition, and in the AHR condition no one enters the specification.

## Filtrate

**Table 10. Filtrate Measurement Results**

	Base (ml)	NaCl 3% (ml)	NaCl 4% (ml)	NaCl 5% (ml)
AHR	2.2	1.8	2.4	1

From the results of the filtrate test from the base sludge to the NaCl 3%, NaCl 4% and NaCl 5% contamination sludge all meet the specifications.

## Power of Hydrogen

Based on the data obtained from the results of the sludge pH test, all sludge with the addition of a few percent of NaCl the PH value experienced changes in both conditions. This result was obtained from the analysis of 44 pH of the sludge using a digital pH tool.

**Table 11. pH Observation Results**

	Base	NaCl 3%	NaCl 4%	NaCl 5%
BHR	10.5	13.29	13.37	12.4
AHR	10.2	10.05	10.75	7.98

From **Table 11** it shows that the specifications that enter the specification are only in the base sludge in the BHR condition, and in the AHR condition that enters the base sludge specification up to the NaCl 3% and NaCl 4% sludge.

## Methylene Blue Test (MBT)

The MBT method is one of the fastest and most accurate methods for detecting clay minerals in fine aggregates.

**Tabel 12. MBT Observation Results**

Base (lb/bbl)	NaCl 3% (lb/bbl)	NaCl 4% (lb/bbl)	NaCl 5% (lb/bbl)
5	4	4	No Testing

From the results of the filtrate test from the base sludge to the NaCl 3%, NaCl 4% and NaCl 5% contamination sludge all meet the specifications. From the above results on 5% NaCl contamination sludge, no results were obtained due to the non-continuation of MBT testing because the sludge at the time of *rheology* testing was *overscale*.

Based on **Table 13** which is the result of mud properties obtained from the addition of NaCl contamination there are similarities, decreases and increases in several property values that have been tested, the results of testing with the addition of several percent of NaCl contamination are dominated by a decrease in AHR conditions in several properties ranging from viscosity, plastic viscosity, yield point, low share rate yield point, gels strength, filtration loss, pH, MBT, and excess amine, but also experienced an increase that is directly proportional to the number of percent additions of contamination added to the test, the higher the percentage level of addition of contamination added to the test, the higher the percentage level, the higher the value of some of these properties. In **Figure 2** which is a graph between the variation of NaCl on the properties of the drilling mud tested.

Testing of the physical properties of drilling mud to determine the results of mud properties that are in accordance with the existing range and specifications. It can be assumed that changes in the physical properties of drilling mud with the addition of NaCl depend on the amount or lack of NaCl concentrations added or contaminated into the drilling mud, regular monitoring of the properties and conditions of the well is essential to identify and address problems due to NaCl contamination as early as possible. The results of this research show that the use of water-based mud systems with shale inhibitor formulations has significant potential in overcoming the problem of clay formation reactivity.

**Table 13. HPWBM Observation Results**

Properties	Specs	Base BHR	NaCl 3%	NaCl 4%	NaCl 5%	Base AHR	NaCl 3%	NaCl 4%	NaCl 5%
Mud weight, lb/gal	1.60-0.01					1.15	1.56	1.58	No Testing
Rheology @150F									
600 rpm		275	220	292	OS	204	142	144	105
300 rpm		213	197	236	259	144	89	95	69
200 rpm		163	162	203	225	113	68	71	51
100 rpm		125	119	152	178	75	43	44	27
6 rpm		46	29	39	52	18	5	4	2
3 rpm		37	19	26	37	14	3	3	1
PV (Plastic Viscosity), cp	ALAP, <45	62	23	56	No Testing	60	53	56	36
YP (Yield Point), lbs/100ft2	20-35	151	174	180	No Testing	84	36	46	33
LSR YP, lbs/100ft2	5-10	28	9	13	22	10	1	2	0
Gel Strength 10 sec, lbs/100ft2	7-12	30	11	16	No Testing	11	1	1	1
Gel Strength 10 min, lbs/100ft2	10-28	42	20	20	No Testing	6	2	3	2
Filtrate API (100 psi), ml/30 min	<4					2.2	1.8	2.4	No Testing
PH	9.5-11.0	10.5	13.29	13.37	12.4	10.5	10.05	10.75	7.98
MBT, ppb	<5					5	4	4	No Testing
POLYAMINE	1.7-2.0					1,6	1,6	1,7	No Testing

Figure 2 shows the effect of adding 3%, 4%, and 5% NaCl on several key drilling mud parameters, namely Plastic Viscosity (PV), Yield Point (YP), Low Shear Rate Yield Point (LSRYP), 10-second Gel Strength (GS 10 DTK), 10-minute Gel Strength (GS 10 MNT), API Filtrate, and pH. The PV value experienced a slight decrease from the base condition to the addition of 3% NaCl, then remained relatively stable at 4% NaCl, and decreased again at 5% NaCl. The YP value showed a downward trend with increasing NaCl concentration. From the base condition, the YP value decreased quite significantly at 3% NaCl, increased slightly at 4% NaCl, and then decreased again at 5% NaCl. The LSRYP value increased from the base condition to 4% NaCl, then decreased slightly at 5% NaCl. The 10-second gel strength

value experienced a very significant decrease from the base condition to 3% NaCl, then remained relatively constant up to 5% NaCl. The 10-minute gel strength also showed a downward trend after the addition of NaCl. A slight increase occurred at 4% concentration, but decreased again at 5%. The API filtrate volume tended to increase from baseline to 4% NaCl, then remained relatively stable at 5%. The pH value showed a relatively stable trend in the range of around 8–10 throughout the test. However, there was a slight decrease at 5% NaCl.

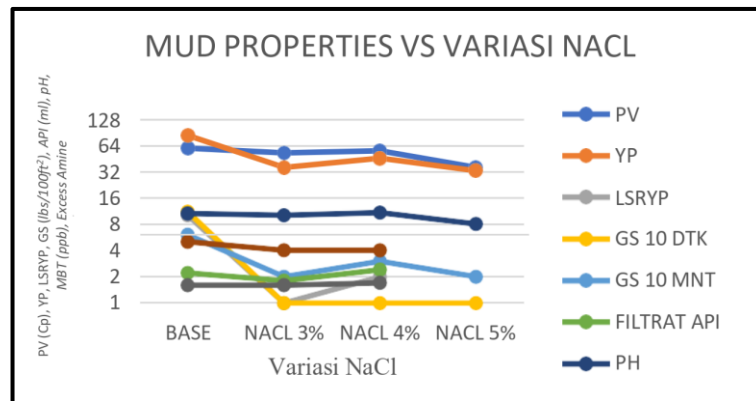


Figure 2. Variation of NaCl on the Properties of the Drilling Mud Tested

The experimental results demonstrated that the addition of NaCl contamination at varying concentrations predominantly led to a reduction in several drilling fluid properties under AHR conditions, including viscosity, plastic viscosity, yield point, low shear rate yield point (LSRYP), gel strength, filtration loss, pH, methylene blue test (MBT), and excess amine. Furthermore, the extent of these changes was directly proportional to the concentration of NaCl contamination introduced. Higher NaCl contamination levels produced more significant variations in the measured properties, indicating a strong influence of salt contamination on the overall performance of the drilling fluid system.

### CONCLUSION

The results of the test showed that the reaction of HPWBM Polyamine sludge resulted in a change in the physical properties of the base sludge condition and the addition of 3%, NaCl 4% and 5% NaCl contaminants where in the BHR condition *the rheological* value was close to the specification only NaCl 3%, then in the AHR condition that entered the specification only in the base sludge in the LSRYP and Gel Strength measurements of 10 seconds, and in the comparison of three different conditions having different mud properties values due to NaCl contamination, so that the result is obtained where the condition of BHR sludge of 3% NaCl contaminant is more suitable for the specification, while in the condition of AHR the sludge of 4% NaCl contaminant is more in accordance with the specified specifications. And also The effect of NaCl contamination on the HPWBM Polyamine sludge system can affect the physical properties of drilling sludge such as the higher the NaCl presentation, the more the viscosity value increases, but the higher the presentation of NaCl can also reduce the reactivity of clay in drilling mud so that the mud becomes more stable to swelling clay, and the higher the NaCl presentation, the higher the acidity level of the drilling fluid, thereby increasing the potential for corrosion from the sludge.

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