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POTENTIAL USE OF POLYSACCHARIDES NATURAL POLYMER IN PLANTS AS AN ALTERNATIVE TO CHEMICAL ENHANCED OIL RECOVERY (EOR) TO INCREASE OIL PRODUCTION IN INDONESIA

Muhammad Irtin Syariefudin
Faculty of Engineering, Universitas Islam Riau, Indonesia
Email: syariefudinmuhammadirtin@gmail.com

ABSTRACT

The decline in oil production in the past few decades has made Enhanced Oil Recovery (EOR) one of the technologies that get more attention because it has been proven to increase oil production in a field. One EOR method that is widely used today is by injecting chemicals in the form of polymers. Polymers themselves are grouped into two types, namely synthetic polymers and natural polymers or known as biopolymers. The use of synthetic polymers has limitations, especially in oil reservoirs that have high temperatures and salinity levels, therefore the development of biopolymers is an interesting thing to study, in addition to the availability of raw materials in large quantities, this type of polymer has good mechanical properties and is easy to make derivatives according to the desired properties and characters. The use of biopolymers is considered cheaper and safer because they come from natural materials so that they can be decomposed properly. Therefore, the researcher tried to make a comprehensive brief review of the reasons for the importance of using polymers in EOR activities in Indonesia, a comparison of the properties, characteristics, advantages and disadvantages of the two types of polymers, along with the progress of several research results that have been carried out previously. this research is expected to provide useful insights about the potential use of natural materials as basic materials in the process of making biopolymers, properties and characteristics that are resistant to bacteria and high salinity.

KEYWORDS Enhanced Oil Recovery; Injection Polymer; Syntetic Polymer; Biopolymer; Mature Field

INTRODUCTION

The trend of decreasing oil production in recent years is always interesting material to study together. Based on data quoted from the annual report (SKK Migas, 2019), domestic oil and condensate production reached 745.1 thousand barrels of oil per day

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(BOPD) or decreased by 26.96 thousand BOPD when compared to production in 2018 which reached 772.1 thousand BOPD. According to (Abdurrahman, Bae, Novriansyah, & Khalid, 2016), this matterThis occurs because many oil fields in Indonesia have entered the mature field category. Therefore (Alvarado & Manrique, 2010; Ogezi, Strobel, Egbuniwe, & Leonhardt, 2014), apart from continuing to carry out exploration efforts, more advanced technology is needed to increase oil productivity in the field again by implementing the Enhanced Oil Recovery (EOR) method.

Several types of EOR methods available, chemical injection uses polymers (*polymer flooding*) has been proven to be able to increase oil production in fields that previously used water flooding (Abdurrahman, 2017). This method is widely used in the field because its application is considered relatively easier and simpler, even in research (Abidin, Puspasari, & Nugroho, 2012a) revealed that the oil recovery with this method is much greater than the water flooding method, reaching 5-30% of the Original Oil In Place (OOIP). The same thing was also stated by (Pope, 2007) who reported that the addition of 0.7-1.75 lb of polymer injected into the well was able to increase oil production by 1 barrel.

By type (Mandal, 2015; Obuebite, Onyekonwu, Akaranta, & Uzoho, 2018) divides polymers into two namely synthetic polymers and biopolymers, of the two types of polymers synthetic polymers in the form of hydrolized polyacrylamide (HPAM) and xanthan gum biopolymers are the polymers most widely used in EOR activities (C. Gao, 2016; Sheng, 2011). Both polymers actually have their own advantages and disadvantages, just like HPAM and its derivatives, although it is widely known that it can increase viscosity very well even at low concentrations, this has even been proven by many studies reporting their success.in increasing oil recovery significantly (Abbas, Sanders, & Donovan, 2013). However, this type of polymer is very sensitive to high temperatures and salinity.

Even (Rashidi, Blokhus, & Skauge, 2010) revealed that if the presence of Ca2 + or Mg2 + ions in the formation water can cause sediment to form which can clog rock pores so that the use of this type of polymer will be very limited for offshore reservoirs. Moreover, oil reservoirs in Indonesia generally have temperatures ranging from 160°C to 200°C (Abidin, Puspasari, & WA Nugroho, 2012), so that in reservoirs that have temperatures above 95 °C and salinity above 90,000 ppm, synthetic polymer types such as Acrylamide (AM), Polyacrylamide (PAM), *Hydrolyzed Polyacrylamide* (HPAM) cannot be used (Carolina et al., 2019).

Whereasxanthan gum based biopolymer, although it has extraordinary performance in formations with high levels of salinity (20 gr/L), is resistant to temperatures up to 135 °C and is even known for its relative compatibility with most surfactants and other injection additives, this type of polymer turns out to be vulnerable experiences degradation due to bacteria, so the use of biocides to overcome this problem often makes the application of xanthan gum considered more expensive when compared to synthetic polymers (Abidin, Puspasari, & WA Nugroho, 2012; De Itriago & Fresky, 2019).

Moving on from these problems, a brief review was made which presented a comprehensive discussion of the reasons for the importance of using polymers in EOR activities in Indonesia, the differences in their properties and characteristics along with the advantages and disadvantages of both, then also some of the results of biopolymer tests that had been carried out previously. It is hoped that this research will provide useful insights regarding the potential use of natural materials as raw materials in the manufacture of biopolymers so that it is possible that new ideas will emerge in creating or engineering biopolymers with capabilities that will continue to experience improvement and refinement in the future.

RESEARCH METHOD

Methods for producing petroleum

At the beginning of production, oil can still flow naturally (natural flow) as shown in the scheme below (Figure 1). This is because the pressure in the reservoir is still high enough to naturally push the oil to the surface, but as production time goes by, the pressure in the reservoir will gradually decrease so that to optimize the oil production again, artificial methods are applied. lifts such as the use of pumps or gas lifts so that the fluid column becomes lighter so that oil can flow back optimally, even though the facts in the field show that this method is only able to drain oil around 5-15% of the oil reserves that can be produced (Kristanto, 2010).

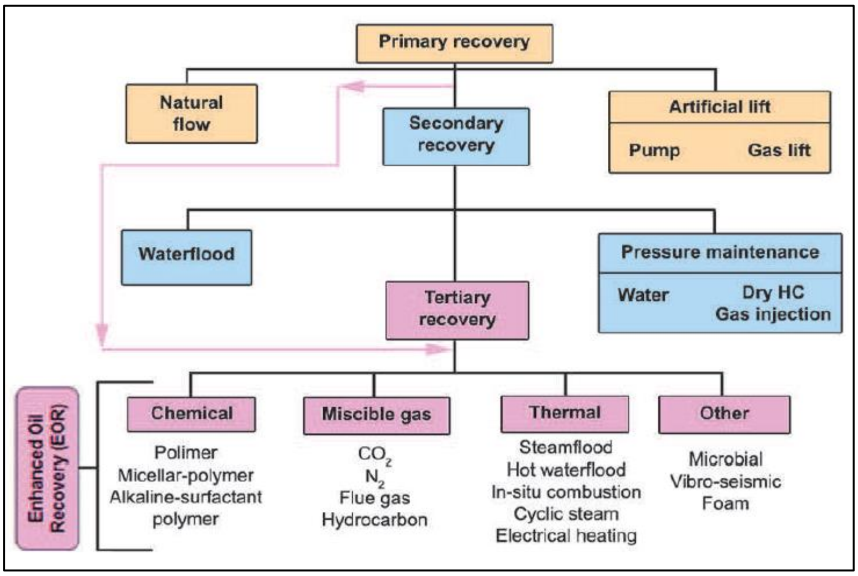

Figure 1. Stages of draining oil in the reservoir (Usman, 2011)

Whenthe use of the artificial lift method is no longer optimal for continued use, so the second stage of oil extraction (secondary recovery) is carried out, namely by injecting gas or water through injection wells to urge and replace the position of oil in the rock so as to force the oil to move towards the production well , this method usually targets an additional recovery factor of 30-40% although this figure may be more or less depending on the type of oil and surrounding rock (Widyarso, Swadesi, & Vishnu Aji Wibowo, 2006). This shows that in the reservoir there is still quite a large amount of oil which cannot be produced optimally using the two previous methods.

In his research (Wibowo, Buntoro, & Natsir, 2007) revealed that this could be caused by the imperfect pressing and sweeping process of oil because the mobility of water is much greater than the mobility of oil. Apart from that, there is also the influence of rock heterogeneity and additionally the residual oil which is firmly attached to the rock matrix as a result. So as to maximize production under these conditions (Sheng, 2011) suggest using the advanced oil extraction method, known as Enhanced Oil Recovery (EOR).

Enhanced Oil Recovery (EOR) is a method used to increase oil production (recovery factor) by changing the physical and chemical properties of both the fluid and the reservoir rock (Alvarado & Eduardo, 2010; Sheng, Leonhardt, & Gmbh, 2015). Several reasons behind the application of the EOR method in an oil field include:

1) The ineffectiveness of the primary recovery and secondary recovery methods used is indicated by a significant downward trend in oil production (Sheng, 2011).

2) The influence of the high selling price of crude oil has made many oil and gas companies interested in investing in the hope of getting bigger profits.
3) The demand for oil continues to increase every year, this will also influence the direction of future policy.
4) Considering the risk of failure in exploring, this often makes companies issue strategies and policies to play it safe by first producing the remaining oil in the reservoir (remaining reserve).

The Importance of Implementing EOR in Indonesia

Before 2004, Indonesia was one of the oil exporting countries in the world, even in 1962 Indonesia was listed as a member. *Organization of Petroleum Exporting Countries* (OPEC). However, along with the increasing demand for oil which is not matched by the amount of domestic production as shown in (Figure 2) below, forcing Indonesia to import oil from other oil-producing countries to fill the shortfall in domestic oil supply.

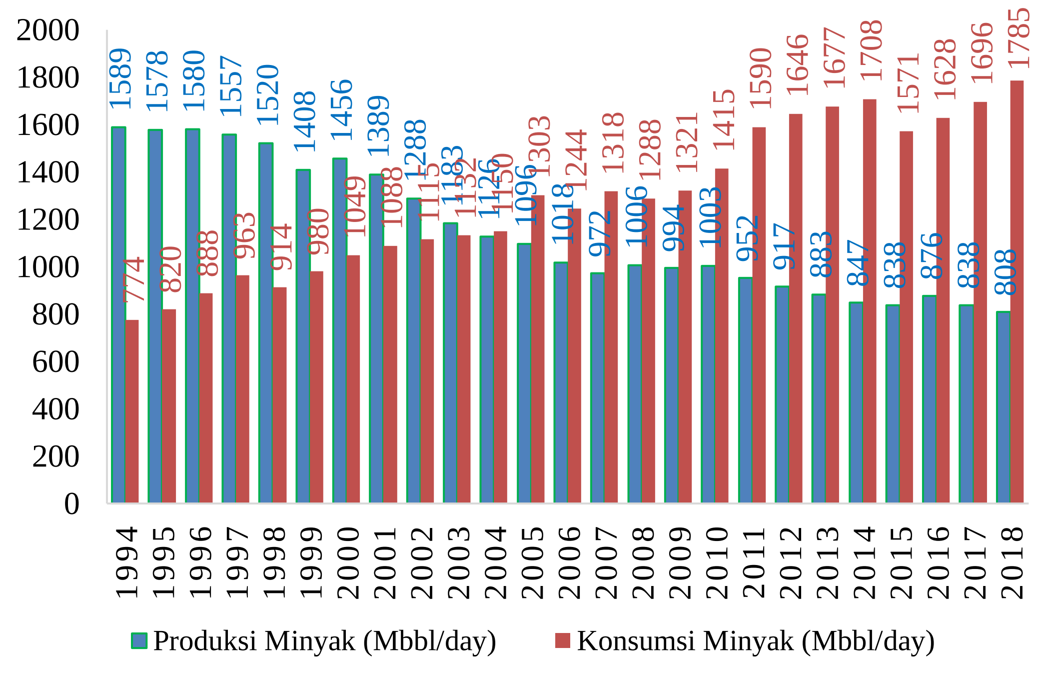

Figure 2. Comparison of oil production and consumption in Indonesia
(BP Statistics, 2016, 2019)

Based on the report above (BP Statistical, 2019), Indonesia's oil production in 2018 was 808,000 BOPD while consumption reached 1,785,000 BOPD. This shows that in 2018 Indonesia could only meet half of its total domestic oil needs. In fact, it is estimated that Indonesia's total oil consumption in 2030 could reach 3,970,000 BOPD. Therefore, to maintain national energy security, it is necessary to take steps that are considered appropriate and effective to maximize the Initial Oil In Place (IOIP) draining process by implementing Enhanced Oil Recovery (EOR) to maintain and increase production rates, considering the process Exploration to find oil reserves in new fields requires a lot of time and a lot of money (Wicaksono & Yuliansyah, 2015).

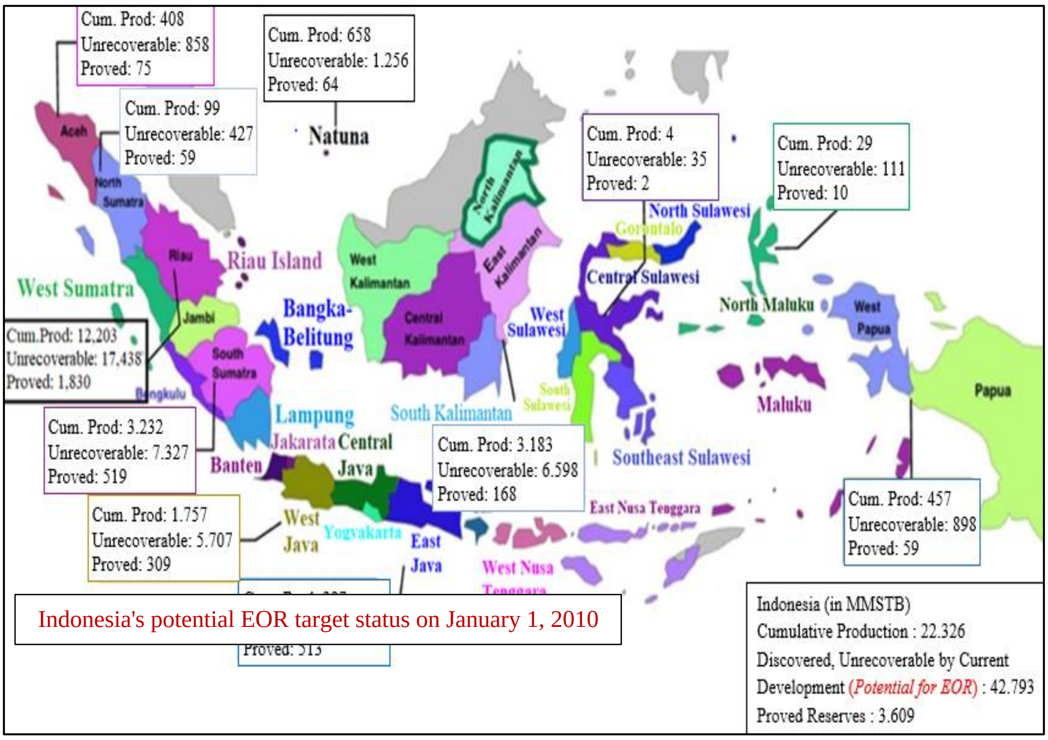

Figure 3. Map of EOR potential in Indonesia (Usman, 2011)

From the cumulative production data on oil reserves in various regions as shown in (Figure 3) above, it can be seen that there are still many oil reserves that have not been produced optimally using artificial lift or water flooding and gas flooding. This shows the large potential for implementing EOR in Indonesia.

One EOR method that can be used to overcome this problem is by usinginjection of chemicals in the form of polymers. This method has the potential for considerable success in oil fields that have previously implemented water flooding although in practice the success of polymer flooding is still influenced by permeability, temperature and the type of reservoir itself (Wibowo et al., 2007). Even in the report (Alfazazi, AlAmeri, & Hashmet, 2019) revealed that there was an increase in total production of 20% after the pilot project carried out in several oil fields in China, Germany and Oman was declared successful.

Polymer Injection (Polymer Flooding)

Polymers are giant molecules (macromolecules) made up ofa series of repeating structural units (monomers) linked together by chemical bonds.When amount monomer very big, compound the called polymer with heavy molecule tall. Temporary polymer with heavy molecule more low sometimes called as *dimer*, *trimer*, *tetramer*, *pentamer*, and so forth (Bhat & Kandagor, 2014).

The use of this polymer has spread widely in various industries ranging from the food, textile, construction, chemical, agricultural, transportation, to oil and gas industries (Xin et al., 2018). In the petroleum industry, polymer flooding has proven to be one of the most promising chemical EOR (CEOR) technologies for increasing sweep efficiency and oil displacement (Moreau et al., 2010). This is supported by (Mandal, 2015) which states that one of the EOR chemicals that has been proven to be able to increase oil production in fields that have historically implemented water flooding is polymer. Even (Mohsenatabar

Firozjaii & Saghafi, 2020) in its report, it states that of all EOR projects carried out in various parts of the world, more than 77% of the chemicals used are polymers.

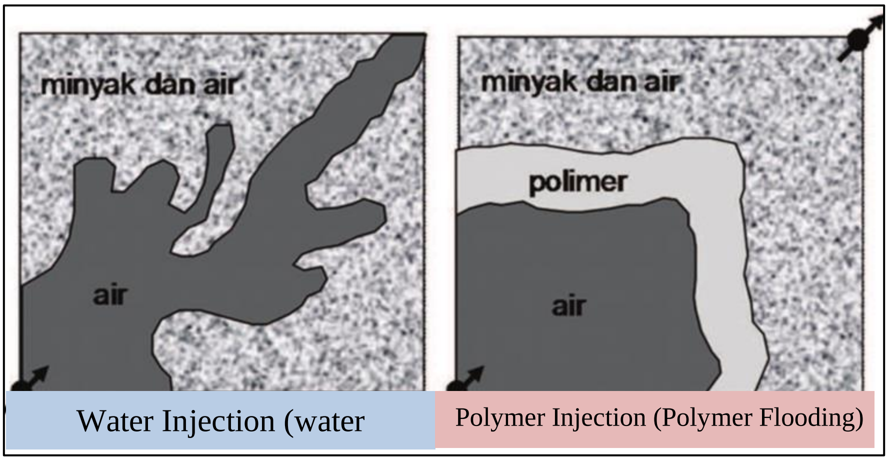

Figure 4. Schematic of oil sweeping in rock pores (Usman, 2011)

From the illustration results of the oil sweeping process in the pores of the reservoir rock as shown in (Figure 4) above, it can be seen that the addition of polymer into the*water injection*as a thickening agent it will increase the viscosity of the injection water, causing a decrease in the mobility ratio between water and oil (Rellegadla, Prajapat, & Agrawal, 2017; Rita, 2012) while also reducing the relative permeability of water in the reservoir (Bahadori, 2018), as a resultwater will have a much greater ability to encourage oil attached to the rock matrix to move towards the production wellbore as shown by (Figure 5) below.

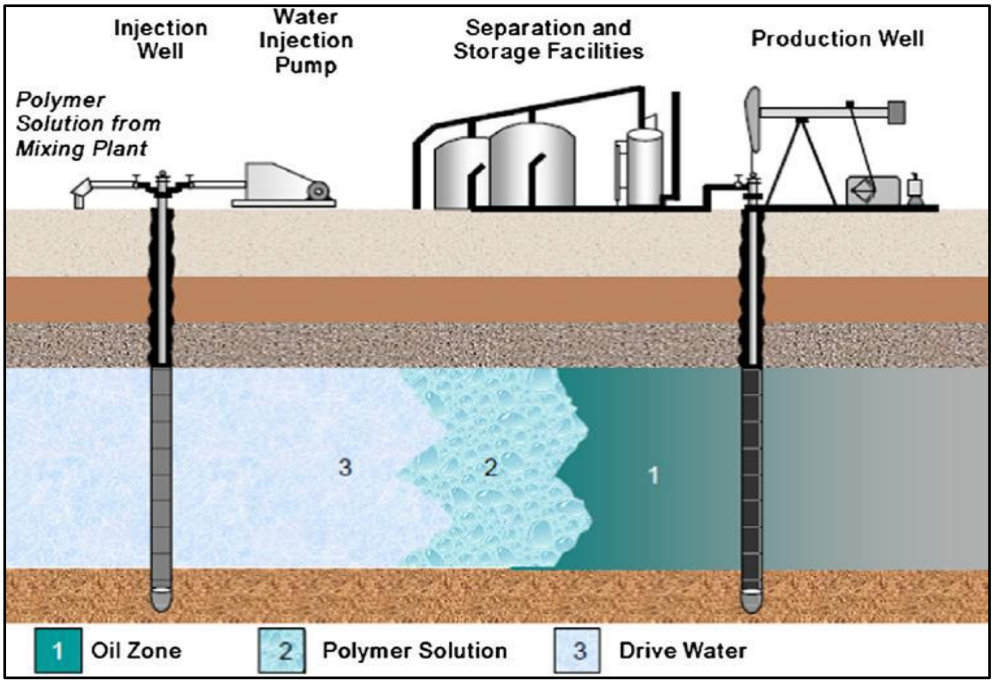

Figure 5. Illustration of Polymer Injection (El-hoshoudy et al., 2017)

In the report (Seright, Campbell, Mozley, & Han, 2010), revealed that the addition of polymer to injection water can both encourage and flow oil to production wells with a record oil viscosity ranging from 15 cp to 1,000 cp. Even (Taber, Martin, & Seright, 1997) adding that polymer injection is suitable and can be used in reservoirs with relatively low oil viscosity up to 150 cp.

Use of polymers as*chemical* EOR has been practiced for the last 20-30 years (Tengku Mohd et al., 2018). Even (Rostami, Kalantari-Meybodi, Karimi, Tatar, & Mohammadi, 2018) shows that this method has been used since the early 1960s and is widely used because its application is relatively simple and effective for controlling fluid mobility (Quadri et al., 2015). Research result (Huiqing, Hongling, & Peixi, 2007; L. Wang, Xu, Guo, Peng, & Tang, 2011) in Chinese oil fields, indicating that the appropriate polymer concentration to increase oil production should be higher than 1,500 ppm. This is in accordance with research conducted by (D. Wang, Han, Shao, Hou, & Seright, 2008) who found thatPolymer injection in China's Daqing oil field was able to increase total production by around 22.3% in 2007 after first being used in 1996 (Pope, 2007).

Initially, chemical injections were carried out using chemicals in the form of polymers, alkalis and surfactants. However, with the large amount of research that has been carried out to develop the chemical injection method, it is not uncommon for polymer injection to also add additives in the form of surfactants, alkalis or a combination of the three, as in the pilot project which has been successfully carried out in the Kaji, Hopefully, Limau and Tanjung Oil Fields (SKK Migas, 2017). This shows the important role of polymers in the petroleum industry.

In the report (Kristanto, 2010) revealed that the injection combination of polymer and surfactant or so-called Micellar-Polymer Flooding was proven to be able to increase oil recovery. This was reinforced by the results of laboratory studies (Damanik, Kasmungin, & Sudibjo, 2018) which stated that the addition of SPA polymer solution with a concentration of 1,600 ppm into A surfactant solution with a concentration of 1% at a salinity of 12,000 ppm can increase the recovery factor to 84%.

Synthetic Polymers

Synthetic polymers are man-made polymers that are formed from simple chemical synthesis,have flexible molecules with polymer bonds consisting of relatively stable carbon (C) molecular chains. One of the synthetic polymers commonly used in EOR activities is Hydrolysed Polyacrylamide (HPAM) which has the following chemical structure:

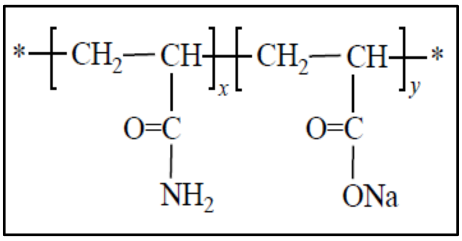

Figure 6. Chemical structure of HPAM (Sheng, 2011)

In general, synthetic polymers have good viscosity in fresh water and also have good adsorption capabilities on rock surfaces. However, these polymers exhibit poor thermal stability and will hydrolyze at high temperatures, thereby creating a higher charge density of anionic functionalities along the polymer backbone, this phenomenon tends to reduce the viscosity of the polymer solution thereby making the entire polymer injection process inefficient (Mohsenatabar Firozjaii & Saghafi, 2020).

In addition, this group of polymers is very sensitive to salinity, flow rate, shear force, pH, and also hardness (Gbadamosi, Junin, Manan, Agi, & Yusuff, 2019; Mohsenatabar Firozjaii & Saghafi, 2020). The disadvantages of this synthetic polymer have limited its application to reservoirs with high temperatures and high salinity (High Temperature and High Salinity). Even (Sheng, 2011) and (Seright et al., 2010) also explained that when the degree of hydrolysis is more than 40% at temperatures above 60 °C, the acrylamide group in HPAM will undergo hydrolysis to form an acrylate group. At higher levels of hydrolysis (greater than 40%), the flexible chains of HPAM are compressed and distorted, resulting in a decrease in viscosity. In addition, HPAM can form precipitates with Ca2+ and Mg2+ cations in solutions with high salinity (Choi, Jeong, & Lee, 2014).

In his research (Brock & Shiel, 1983) dividing the level of salinity of a brine into several groups based on its concentration, the first is fresh water below 3,000 ppm, the second is slightly saline between 3,000 – 10,000 ppm, then saline 10,000 to 35,000 ppm and the last is hypersaline above 35,000 ppm. Although (Frigrina, Kasmungin, & Mardiana, 2017) in his report said that the average salinity for oil reservoirs in Indonesia is 15,000 ppm. The application of synthetic polymers in EOR is presented in Table 1 below.

Table 1. Application of synthetic polymers in the field

No	Fields	Polymer products	characteristic
1	Daqing Oilfield, China (Onshore) (D. Wang et al., 2008)	HPAMs	a) Polymer solution viscosity, mPa·s: 35–40 b) Polymer solution concentration, mg/L: 1,000 c) Sandstone reservoirs d) Reservoir temperature 45 °C
2	Shengli Oilfield, China (Onshore) (CH Gao, 2014)	HPAMs	a) Formation water salinity, mg/L: 10,000 b) Polymer solution concentration, mg/L: 5,000 c) Apparent of polymer viscosity, mPa·s: ≥ 11.5 d) Sandstone reservoirs e) Reservoir temperature 70 °C
3	Dalia Offshore Oilfield In Angola (Offshore) (Morel, Zaugg, Jouenne, Danquigny, & Cordelier, 2015)	HPAMs	a) Formation water salinity, g/L: 110–120 b) Polymer solution concentration, mg/L: 900 c) Formation water salinity, mg/L: 20,000 d) Polymer solution viscosity, mPa·s: 7.5 e) Sandstone reservoirs f) Reservoir temperature 50 °C
4	El Corcobo Norte field, Argentina (Onshore) (Hryc, Hochenfellner, Paponi, Puliti, & Gerlero, 2013)	HPAMs	a) Polymer solution concentration, mg/L: 1,400 b) Formation water salinity, mg/L: 46,000 c) Sandstone reservoirs d) Reservoir temperature 38 °C
5	East Bodo oilfield, Alberta Canada (Onshore)	HPAM	a) Polymer solution concentration, mg/L: 500–1500 b) Polymer solution viscosity, (mPa·s): 25

(Wassmuth, Green, Arnold, & Cameron, 2009)	c) Sandstone reservoirs d) Reservoir temperature 23 °C

Biopolymer

Biopolymers are a type of polymer formed from organic materials (Widyarso et al., 2006) this is why this type of polymer can easily be found in the contents of animal and plant cellsand other micro-organisms in the form of cellulose, chitin, chitosan, dextran, starch, and xanthan gum (Benabid FZ & Zouai, 2016). Even (Sveistrup, van Mastrigt, Norrman, Picchioni, & Paso, 2016) revealed that this biopolymer can also be produced from chemical synthesis from other natural materials.

The use of biopolymers for oil and gas applications is very attractive because they are economically effective and the production costs are cheap compared to using synthetic materials, besides that natural polymers are known to be non-toxic, safer to use, and biodegradable (Kulkarni, Butte, & Rathod, 2012). The division of biopolymer according to (Kaushik, Sharma, Agarwal, & Pradesh, 2016) can be seen in (Figure 7) below:

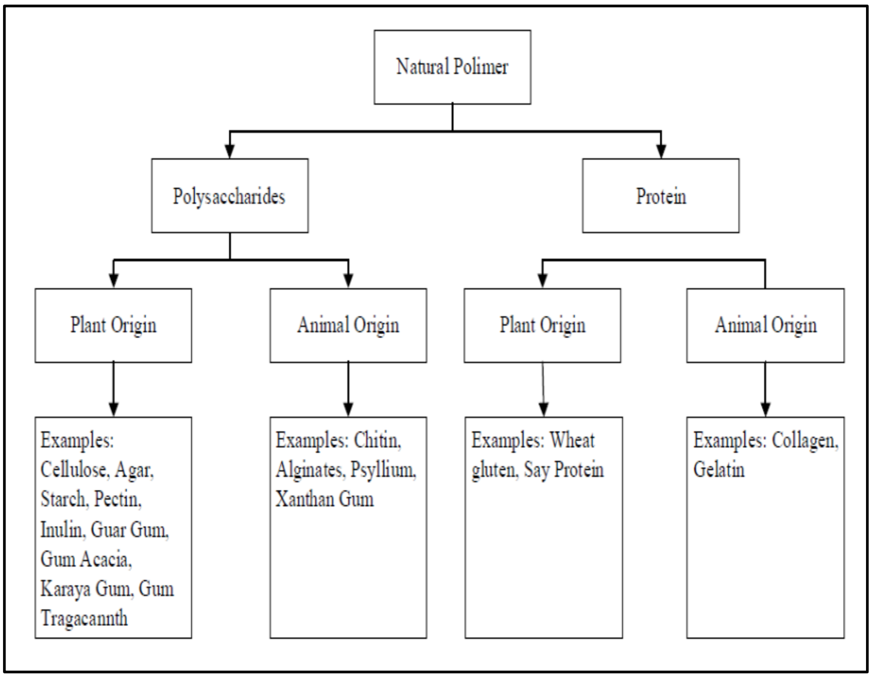

Figure 7. Biopolymer classification (Kaushik et al., 2016)

The advantages of biopolymers include having a viscosity that is suitable for high salinity, but is not suitable when mixed with fresh water (Rendón-Villalobos, Ortíz-Sánchez, Tovar-Sánchez, & Flores-Huicochea, 2016). Some examples of these biopolymer derivatives include Xanthan Gum, Guar Gum, Sodium Carboxy Methyl Cellulose (Na-CMC), Hydroxy Ethyl Cellulose (HEC) and so on (Sheng, 2011).

Xanthan gum is one of the biopolymer products that has also been widely applied in EOR activities, this type of biopolymer is produced by bacteria and is one of the first commercial bacterial polysaccharides to be successfully produced through the fermentation of xanthomonas compestris (Abidin, Puspasari, & Nugroho, 2012b; Kim et al., 2015). It has the form of a cream-colored powder that quickly dissolves in hot or cold water to form a thick, non-thicotropic solution (Kulkarni et al., 2012) with the following chemical structure:

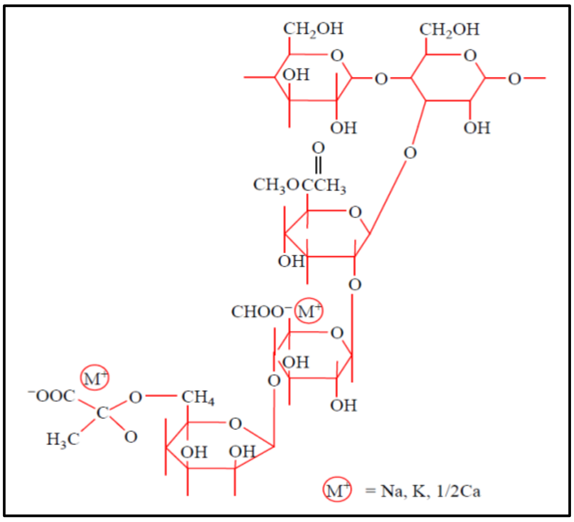

Figure 8. Chemical Structure of Xanthan Gum (Rosalam & England, 2006)

The application of biopolymers in EOR activities is presented in (Table 2) below:

Table 2. Application of Biopolymers in the Field

No	Fields	Status	Biopolymer Type	Characteristic
1	SZ36-1 Oilfield in Bohai Oilfield, China (Offshore) (Han, Xiang, Zhang, Jiang, & Sun, 2006)	Pilot and further applications	Xanthan Gum	a) Calcium and magnesium components, mg/L): 568; 228 b) Sandstone reservoirs
2	Eddesse-Nord Sandstone Reservoir, Germany (Onshore) (Littmann, Kleinitz, Christensen, & Stokke, 1992)	Pilot Project	Xanthan Gum	a) Concentration of xanthan solution, (ppm): 800 b) Salinity of reservoir brine, g/L: 120 c) Salinity of injection water, g/L: 50 d) Viscosity of biopolymer, mPa·s: -12 e) Sandstone reservoirs
3	Safaniya Oilfield, Saudi Arabia (Onshore) (El-Sayed, 1996)	Laboratory models	Xanthan Gum	a) Molecular weight, g/mol: 9.6×10^6 b) Polymer concentration, %: 0.15, 0.20 c) Formation water salinity, %: 3.5 d) Sandstone reservoirs
4	The Sabriya-Maudud (Sama) Reservoir, in Kuwait (Onshore) (Al-Saleh, Yussuf, Jumaa,	A methodology for the preparation and characterization	SPG (Schizophyllan)	a) An optimal viscosity of 35 mPa·s at 22°C b) Acceptable salinity for use, g/L: 180 c) Carbonate reservoir

No	Fields	Status	Biopolymer Type	Characteristic
	Hammoud, & Al-Shammari, 2019)			
5	Safaniya oilfield, saudi arabia (onshore)(El-Sayed, 1996)	Laboratory models	Xanthan Gum	a) Molecular weight 9.6 x 106 gr/mol b) Polymer concentration 0.15 % – 0.20 % c) Sandstone reservoirs

In the report (Standnes & Skjevrak, 2014) made a literature review regarding the full implementation of polymer injection by collecting 72 well-documented projects from 1964 to 2014, of which the two types of polymers most widely used are synthetic polymers supplied as hydrolyzed polyacrylamide (HPAM) with molecular weight and degree of hydrolysis. which vary and the second is biopolymers as shown by (Figure 9) below.

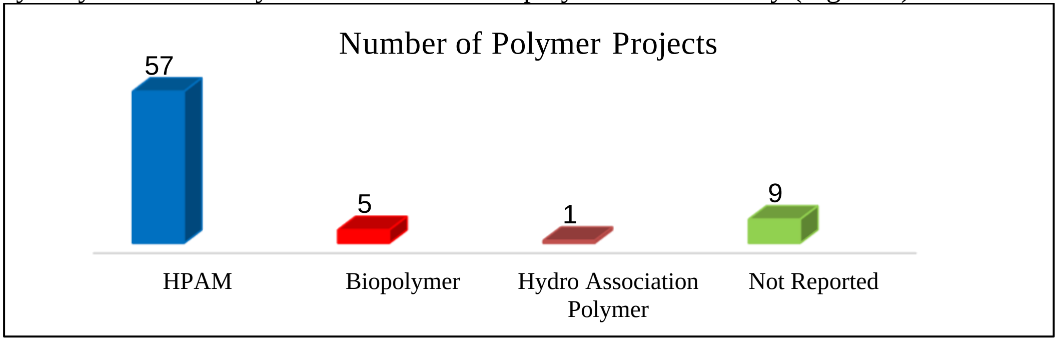

Figure 9. The type of polymer that is often used in EOR projects
(Standnes & Skjevrak, 2014)

Even in research (De Itriago & Fresky, 2019) reported that around 92% of polymer flooding project implementations in the field used HPAM while the remaining only 8% used biopolymer.

Parameters supporting the success of Polymer Injection

During the polymer flooding process, several parameters such as polymer concentration, compatibility, viscosity, salinity level, and reservoir temperature have a very important role in determining the success or failure of an EOR project in Lapangam. Usually the concentration used ranges from 250 ppm – 2,000 ppm (Arina & Kasmungin, 2015), while brine salinity ranges from 3,000 ppm – 213,000 ppm (Mohamid et al., 2015) with a polymer viscosity of less than 100 cp (Sheng et al., 2015)

Several pImportant parameters that can affect the Polymer Flooding process include polymer concentration, salinity, temperature, polymer viscosity and also compatibility. Salinity and temperature levels have a significant influence on the physical shape and strength of the polymer itself, in his report (Eni, Suwartiningsih, & Sugihardjo, 2008) revealed that among the requirements for a polymer to pass the screening criteria for EOR are passing the compatibility test, having good thermal stability and having high viscosity. This aims to ensure that no sediment or emulsion is formed which has the potential to clog the pores of the reservoir rock due to changes in salinity levels and temperature.

Usually, several types of synthetic polymers or biopolymers that have been used for EOR activities have concentrations between 250 ppm – 2,000 ppm (Arina & Kasmungin, 2015), with salinity levels reaching 3,000 ppm – 213,000 ppm (Quadri, Shoaib, AlSumaiti, & Alhassan, 2015) and a viscosity of less than 100 cp (Sheng, Leonhardt, & Azri, 2015).

Therefore before doing polymer injection (Widyarso et al., 2006) reminds several important parameters that must be considered include ensuring that the reservoir has high permeability so that injection is easy, then also having a reservoir temperature of less than 100-200 °F, oil saturation must also be high and no less important the reservoir has a propulsion mechanism water drive.

RESULT AND DISCUSSION

Availability of Raw Materials

Polysaccharides are a source of natural polymers that can be easily found in both animals and plants in the form of starch, cellulose, hemicellulose, lignin, pectin and chitin (Benabid FZ & Zouai, 2016) consists of the elements carbon, oxygen and hydrogen which can be applied to make polymers (Baumberger & Ronsin, 2009).

In Indonesia, there are many sources of natural materials that can be processed into products in the form of biopolymers, starting from plants, animals and other marine biota, but the use of these materials as industrial products is still limited to the initial stages, so there needs to be good synergy between educational institutions. , companies and related government agencies to carry out more comprehensive research and studies to utilize these natural resources (Surdiah, 2000).

One of the source of natural wealth in Indonesia is the abundance of plants. Almost all parts of the plant, from stems, leaves, pulp and skin, contain natural polysaccharides, so a lot of research has been carried out using starch, cellulose, pectin and other ingredients to be processed into Sodium Carboxymethyl Cellulose (Na-CMC) based biopolymers, Carboxymethyl Cellulose (CMC), Hydro Ethyl Cellulose (HEC), Xanthan Gum and so on. Although currently most of the biopolymers produced are still used as additives in the food industry, cosmetics manufacturing, plastic manufacturing, pharmaceutical needs and so on.

Manufacturing Method

To produce biopolymers with the best capabilities, the first step carried out in the laboratory is to carry out the cleaning and extraction process of the basic materials. Each extraction method has its own advantages and disadvantages as presented in (Table 3).

Table 3. Comparison of Polymer Extraction Methods

Method	Excess	Lack
Extraction using water (Chen & Huang, 2019; W. Wang et al., 2022)	It has a cheaper cost and is easy to use, can accelerate the rate of polysaccharide diffusion and increase extraction efficiency with increasing water temperature	Many components other than polysaccharides are also extracted so that these impurity particles will affect the ability of the resulting polymer.
Alkali and Acid Extraction(Chen & Huang, 2019; Penjumras, Rahman, Talib, & Abdan, 2014)	The extraction method is relatively simple	Requires more solution for extraction, there are many residues that are also dissolved
Microwave extraction (W. Wang et al., 2022)	The extraction process is fast, has high efficiency and is safe for the environment	Long heating times are prone to causing polysaccharides to become damaged
Enzyme extraction (W. Wang et al., 2022)	Mild reaction and has a high extraction rate	Enzymes are easily damaged due to external factors and can also damage the polysaccharide structure

Method	Excess	Lack
Super critical fluid extraction (Chen & Huang, 2019)	Has a high extraction rate, has no residue and no pollution	It has more expensive extraction costs, more complicated equipment and also a limited scope of application

Research that has been done

To see how polymer compatibility, the influence of temperature and brine salinity have on the density and viscosity values of the polymer itself, several researchers have conducted preliminary research at the Petroleum Engineering Laboratory at the Islamic University of Riau by making biopolymers from natural ingredients that are easy to find later on their properties and characteristics. The resulting polymer will be compared with commercial polymers in the form of xanthan gum circulating on the market. Some of these studies include the following:

Making biopolymers from Seaweed Cellulose (RL) and Green Grass Jelly (DC) leaves using a simple extraction method with water, the test uses polymer with a concentration of 1,000 ppm - 3,000 ppm and brine salinity between 3,000 ppm - 15,000 ppm. From the results of the research conducted, it was found that the two biopolymers were compatible with formation water salinity, homogeneous and found no precipitate or emulsion at temperatures of 50 °C, 60 °C and 70 °C. However, at the same polymer concentration, the viscosity value of xanthan gum was still higher compared to the two biopolymers. This was seen at a polymer concentration of 3000 ppm and a salinity of 3000 ppm. using temperature differences (Jannah, 2019).

Making biopolymer using a combination of ingredients from Black Grass Jelly and Tapioca (CHT). The research used the same extraction method with water as before. From the results of polymer testing with a concentration of 1,000 ppm - 3,000 ppm and a salinity of 5,000 ppm - 60,000 ppm, it is known that the density of the polymer will increase as the polymer concentration and salinity level increase, however, at the same polymer concentration and salinity level, the density and viscosity values of the polymer solution will decrease with increasing temperature. At a concentration of 1,000 ppm, salinity of 5,000 ppm and testing temperature of 70 °C, the viscosity of the polymer solution combining black grass jelly and tapioca was 2,086 cp while the xanthan gum polymer was 3,526 cp (Cadence, 2021).

Making biopolymers from Orange Peel Pectin (PKJ) using the Microwave-Assisted Extraction method with a polymer concentration of 1,000 ppm - 3,000 ppm and a salinity of 5,000 ppm - 30,000 ppm. From this research it is known that PKJ Biopolymer is susceptible to high salinity, this is proven by the presence of precipitates formed during the compatibility test then at a temperature of 60 °C the viscosity of XG polymer with a concentration of 3000 ppm and a salinity of 5000 ppm is 1.854 cp while PKJ is 0.412 cp. However, one of the advantages of PKJ is that this biopolymer is more resistant to the effects of shear rate compared to xanthan gum. This is proven by the test results. The average decrease in viscosity of xanthan gum reached 4.3 cp, while the average decrease in viscosity for PKJ was 3. 2 cp at RPM 100, 200, 300 and 600 (Setiawan, 2021).

From the results of making Biopolymer from Durian Seed Starch (PBD) with a polymer concentration of 500 ppm – 2,000 ppm and a brine salinity of 5,000 ppm

– 60,000 ppm. It can be concluded that the durian seed starch polymer became incompatible due to the addition of polymer concentration, increase in temperature and salinity so that it precipitated in the solution, added to the polymer concentration of 500 ppm and brine salinity of 5,000 ppm with a testing temperature of 60 °C the viscosity value of PBD Biopolymer is 1,194 cp while Xanthan Gum is 1,326 (MS Wicaksono, 2020)

Manufacture of Na-CMC-based Biopolymer from Cassava Peel using Synthesis, Hydrolysis and Alkalization methods using various concentrations of sulfuric acid (45%, 50% and 55%) with polymer concentrations of 1,000 - 3,000 ppm with a salinity of 5,000 ppm - 15,000 ppm. From the results of the tests that have been carried out it is known that the best hydrolysis process in increasing cellulose content is using sulfuric acid (H2SO4) with a concentration of 45%, then the addition of crosslinker (Cr3+) can increase the viscosity of the polymer to be better than without crosslinker. However, at a polymer concentration of 3000 ppm with a salinity of 5000 ppm and a temperature of 60 °C, the viscosity value of Na-CMC only reached 1.68 cp while Xanthan Gum was 3.62 cp (Irwandi, 2022).

Making Na-CMC-based Biopolymer from Sago Dregs waste which in its extraction process uses the Hydrolysis and Alkalization method with 10%, 15%, 20% and 25% sulfuric acid variations, resulting in the best hydrolysis process using 25% sulfuric acid. At the same polymer concentration and salinity level of 500 ppm and with a salinity of 5,000 ppm - 60,000 ppm the density and viscosity values of the Na-CMC Biopolymer sago pulp still cannot outperform the Xanthan Gum Polymer (Regina, 2021).

Making biopolymer from Cotton Leaves using the Hydrolysis and Alkalization method, using a polymer concentration of 1,000 ppm – 3,000 ppm and a brine salinity of 5,000 ppm – 15,000 ppm concluded that at the same concentration, salinity level and temperature the viscosity value of xanthan gum polymer is still better than polymer from cotton leaves, however, the biopolymer from cotton leaves is more resistant to degradation (Ayu, 2021).

In his research report (Xin et al., 2018) conducted tests on partially hydrolyzed polyacrylamide (HPAM) based polymers to see the effect of polymer degradation that occurs on the effectiveness of the performance of the polymer injection in the field. Based on this research, it is known that the viscosity of the polymer solution will increase with increasing polymer concentration, but as time goes by The polymer solution will decrease with increasing share rate. This is proven that under static conditions the polymer degradation constant value is only 0.0017/day, whereas under dynamic conditions the polymer degradation constant value increases to 0.0022/day. This indicates that polymer degradation has a detrimental effect on karenas can significantly affect the viscosity of the polymer solution to be used later.

CONCLUSION

From the results of several laboratory studies that have been carried out. Polymers from natural materials such as seaweed, grass jelly leaves, cotton leaves, sago pulp, cassava peels and orange peels have the potential and ability to be used in future EOR activities, it's just that further research is needed using more complete equipment to further enhances the performance of these polymers bearing in mind that at the same concentration and salinity the viscosity values of these polymers still cannot outperform the xanthan gum biopolymers that are circulating in the market commercially. Even though (Ayoola et al., 2018) reported that biopolymers produced from potato starch could be an alternative to synthetic polymers because the results of rheological testing, thermal stability and the ability to clog rock pores showed that biopolymers were successfully used for EOR applications. So this shows the potential for further research in the future, regarding the formulation of biopolymers from various other natural ingredients whose properties and characteristics are expected to be in accordance with existing EOR screening.

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