

Description

The present invention relates to a process for the preparation of an aqueous solution of a heteropolysaccharide and the use of such a solution in the production of oil from an underground oil-containing reservoir.

The injection of water to recover oil from underground oil-containing reservoirs is well known in the art. It is also known that the use of a viscosity-increasing agent in the injected water may improve the oil recovery. Some known viscosity-increasing agents are polyacrylamides, copolymers of acrylamides and acrylates, and polysaccharides, i.e. the product obtained from the cultivation of certain bacteria. Polyacrylamides show a viscosity loss in brines and are severely sensitive to shear. Since polysaccharides are relatively shear stable and show little viscosity loss in brines, they are preferred viscosity-increasing agents. They can be used in a viscosified aqueous drive fluid, but they can also be employed in drilling fluids, well completion fluids etc.

Generally, the cultivation of the bacteria is not carried out at the same place as where the polysaccharide is used. In order to reduce transportation costs the polysaccharide is delivered to the place where it is to be used in the form of a concentrate. The concentrate is then diluted with any aqueous medium which is available at this place, yielding a viscous aqueous solution. Aqueous media available at oil fields can be sea water, e.g. at off-shore facilities, and brines emanating from underground reservoirs. Latter brines can have a very high salinity. From British patent specification No. 1,587,225 it is known that when xanthan gum, i.e. the product obtained from the cultivation of *Xanthomonas* bacteria, generally containing mannose, glucose, glucuronic acid and pyruvic acid is used as the polysaccharide type viscosity-increasing agent, plugging occurs in the underground tests. This plugging is thought to result i.a. from precipitation of polymeric salts which occurs when solutions containing multivalent cations are injected into the reservoir. This is in agreement with the Applicant's experience that concentrates of xanthan gum when diluted with a saline, multivalent cation-containing aqueous medium, yield unclear solution which plug the filters used in filterability tests.

It has now surprisingly been found possible to prepare from concentrates of certain heteropolysaccharides and highly saline aqueous media, dilute solutions having useful viscosity characteristics whilst also exhibiting excellent filterability.

The present invention therefore provides a process for the preparation of an aqueous solution of a heteropolysaccharide comprising glucose, galactose, pyruvic and succinic acid and obtained by cultivation of a microorganism, in which process a concentrate of said heteropolysaccharide is mixed with a saline aqueous medium containing from 12 to 30%w of at least one salt, and the mixture obtained is sheared at a temperature ranging from 20 to 100°C, at a pressure in the range 1×10^5 to 15×10^5 Pa, at a sheer rate of 10,000 to 200,000 s^{-1} and at a power input of 0.5 to 10 kWh/m³. The percentages are based on the total of water and salt(s).

Suitable heteropolysaccharides comprise glucose and for each 7 moles of glucose 0.9-1.2 moles of galactose and 0.65 to 1.1 moles of pyruvic acid and up to 2 moles of succinic acid, optionally in combination with acetic acid. Preferably the heteropolysaccharides are obtained from cultivation of *Pseudomonas*-type bacteria, in particular *Pseudomonas* sp. NCIB 11264 (e.g. as described in UK Patent Specification No. 1,539,064), *Pseudomonas* sp. NCIB 11592 (e.g. as described in EP-A-40 445) or microorganism NCIB 11883 (e.g. as described in EP-A-138 255) or mutants thereof. However, cultivation products of other bacteria, such as *Rhizobium* or *Agrobacterium* bacteria, are suitable as well.

The feedstock of the present process is a concentrate. This concentrate is usually such that it can be poured into and out of drums in which it is transported to the oil fields. The heteropolysaccharide concentrate is preferably an aqueous concentrate containing 4 to 15%w of said heteropolysaccharide. These concentrations ensure that on the one hand the feedstock is sufficiently concentrated to avoid unnecessary transportation costs whereas on the other hand it is readily dilutable in an aqueous medium.

Brine or sea water when used as saline aqueous medium with which the concentrate is diluted, generally contains several salts. Usually alkali metal salts, such as sodium and potassium salts are present, together with alkaline earth metal salts such as calcium and magnesium salts. The aqueous medium may further contain minor amounts of other polyvalent metal ions as will be recognised by a person skilled in the art. The pH of the saline aqueous medium is not critical. Both acidic and alkaline media may be employed.

The preparation of the diluted heteropolysaccharide solution can be carried out batchwise. Thereto, a concentrate is fed into a tank, the saline aqueous medium is fed therein, too, in the required quantity, and with a mixing device the admixture is mixed under shearing. Preferably, the concentrate and the saline aqueous medium are mixed and sheared in a continuous manner. Thereto, the concentrate and the saline aqueous medium are introduced into an in line wet comminution machine. In such a machine a great

amount of energy is imparted to the concentrate and the aqueous medium through forces of impact and hydraulic shear. Such machines usually comprise a rotor and a stator. The degree of particle breakdown can be controlled by regulating the gap between the rotor and the stator which are present in such comminution machines. The present invention is not limited to any type of comminution machines. Many types, including machines for batch processes, can be used in the present process.

The extent of dilution can be set at any desired level. The concentration of the solution is generally selected in dependency on the desired viscosity. Preferably, the viscosity of the solution obtained after shearing ranges from 2 to 400 mPa.s, in particular from 5 to 100 mPa.s (at a shearing rate of 7.5 s^{-1} and at 30°C). The solution suitably contains from 100 to 2000ppmw of heteropolysaccharide. The present process will be elucidated by means of the following Examples.

EXAMPLES

Two heteropolysaccharides were tested, heteropolysaccharide I being a 7.7%w concentrate of a *Pseudomonas* NCIB 11592 heteropolysaccharide (as described in EP-A-40 445) containing glucose, galactose, pyruvic acid and succinic acid, and heteropolysaccharide II being a 7.8%w xanthan gum concentrate derived from *Xanthomonas campestris* NCIB 11854 (as described in EP-A-130 647). These concentrates were mixed with one of two brines, brine A comprising 15%w of NaCl and 1.5%w of CaCl_2 in water, and brine B comprising 25%w of NaCl, 2.5%w of CaCl_2 and 2%w of MgCl_2 in water, the weight percentages being based on the total of salts and water.

EXAMPLE I

A series of tests were run using a colloid mill with a slit width of 0.008ft (2.44mm), at a shearing rate of $100,000 \text{ s}^{-1}$, a throughput of 0.23 l/s and a power input of 1.86 kWh/m^3 per pass through the colloid mill. The concentrates were mixed with the amount of brine to achieve a suitable concentration for the mixture and passed 5 times through the colloid mill. After the second and following passes the filterability (Fi) and viscosity of the mixture were determined. The filterability is expressed as the time in seconds in which a litre of the solution is passed through a $1.2\mu\text{m}$ filter at 40 psig ($2.44 \times 10^5 \text{ Pa}$) pressure difference and at 30°C . The viscosity is measured at 30°C and at a shearing rate of 7.5 s^{-1} .

Results of the tests are shown in Table I.

TABLE I

Heteropoly saccharide	Brine	Concentration ppmw	Pass	Fi s	η mPa.s	Power input kWh/m ³
I	A	375	2	113	21.7	3.72
			3	93	21.6	5.58
			4	101	21.7	7.44
			5	92	21.7	9.30
I	B	250	2	244	10.2	3.72
			3	212	10.3	5.58
			4	198	10.4	7.44
			5	203	10.3	9.30
II	A	400	2	blocking	-	3.72
			3	"	-	5.58
			4	"	-	7.44
			5	"	19.6	9.30
II	B	250	2	blocking	-	3.72
			3	"	-	5.58
			4	"	-	7.44
			5	"	9.8	9.30

EXAMPLE II

A second series of experiments were run using a static high shear mixer (Ultra torrax TP 45/4 G). A concentrate and a brine were mixed and subjected to shear at a shearing rate of $100,000 \text{ s}^{-1}$ for a number of seconds. Periodically the filterability and viscosity, as defined in Example I, were determined. The experimental data are indicated in Table II.

TABLE II

Heteropoly saccharide	Brine	Concentration ppmw ppmw	Shearing time, s	Fi s	mPa.s	Power input kWh/m
I	A	375	15	77	21.5	1.36
			30	66	20.2	2.72
			60	55	19.0	5.44
			90	50	17.4	8.16
			120	49	16.8	10.88
I	B	250	15	75	10.6	1.36
			30	67	11.0	2.72
			60	52	10.3	5.44
			180	38	9.3	16.32
II	A	430	30	blocking/40g*	25.5	2.72
			60	blocking/100g	26.0	5.44
			120	blocking/300g	25.4	10.88
II	B	240	60	blocking/70g	9.6	5.44
			120	blocking/230g	9.0	10.88
			180	blocking/900g	8.2	16.32

*The number of grams shown indicates the amount of solution which passed through the filter before blocking occurred.

EXAMPLE III

In an experiment brine B and concentrate of heteropolysaccharide I were supplied to an in line wet comminution machine (Dispax 3-6/6) in such quantities that the resulting mixture contained 250 ppmw of

heteropolysaccharide. The machine was operated at a shearing rate of $43,000\text{ s}^{-1}$, a throughput of $1.6\text{ m}^3/\text{h}$ and a power input of 1.18 kWh/m^3 . After one pass the filterability of the solution was 75 s/l and the viscosity was 11.0 mPa.s at 7.5 s^{-1} and 30°C .

From the above Examples it is apparent that xanthan gum can hardly be dissolved in high salinity brines and no useful product is obtained thereby, whereas heteropolysaccharide I can easily be dissolved at a power input below 10 kWh/m^3 yielding solutions with excellent filterability and viscosity properties. Use of an in line wet comminution machine yields effective solutions at the lowest power input.

Claims

1. Process for the preparation of an aqueous solution of a heteropolysaccharide comprising glucose, galactose, pyruvic and succinic acid and obtained by cultivation of a microorganism, in which process a concentrate of said heteropolysaccharide is mixed with a saline aqueous medium containing from 12 to 30%w of at least one salt, and the mixture obtained is sheared at a temperature ranging from 20 to 100°C , at a pressure in the range 1×10^5 to $15 \times 10^5\text{ Pa}$, at a shear rate from 10,000 to $200,000\text{ s}^{-1}$ and at a power input of 0.5 to 10 kWh/m^3 .
2. Process according to claim 1, in which the heteropolysaccharide is obtained by cultivation of Pseudomonas sp. NCIB 11264, Pseudomonas sp. NCIB 11592 or microorganism NCIB 11883, or mutants thereof.
3. Process according to claim 1 or 2, in which the heteropolysaccharide concentrate is an aqueous concentrate containing 4 to 15%w of said heteropolysaccharide.
4. Process according to any one of claims 1-3, in which the concentrate and the saline aqueous medium are mixed and sheared in a continuous manner.
5. Process according to any one of claims 1-4, in which the viscosity of the solution obtained after shearing ranges from 2 to 400 mPa.s at a shear rate of 7.5 s^{-1} and at 30°C .
6. Process according to any one of claim 1-5, in which the solution contains from 100 to 2000 ppmw of heteropolysaccharide.
7. Use of an aqueous solution of heteropolysaccharide prepared by a process according to any one of claims 1-6 in the production of oil from an underground oil-containing reservoir.

Revendications

1. Procédé de préparation d'une solution aqueuse d'un hétéropolysaccharide comprenant du glucose, du galactose, de l'acide pyruvique et de l'acide succinique qu'on obtient par culture d'un microorganisme, procédé selon lequel on mélange un concentré dudit hétéropolysaccharide avec un fluide aqueux salin contenant de 12 à 30% en poids d'au moins un sel, et on cisaille le mélange obtenu à une température comprise entre 20 et 100°C , sous une pression comprise entre 1×10^5 et $15 \times 10^5\text{ Pa}$, à un taux de cisaillement de 10.000 à 200.000 s^{-1} et avec un apport d'énergie de 0,5 à 10 kWh/m^3 .
2. Procédé selon la revendication 1, dans lequel on obtient l'hétéropolysaccharide par culture de Pseudomonas sp NCIB 11264, Pseudomonas sp NCIB 11592 ou du microorganisme NCIB 11883 ou des mutants de ceux-ci.
3. Procédé selon la revendication 1 ou 2, dans lequel le concentré d'hétéropolysaccharide est un concentré aqueux contenant de 4 à 15% en poids dudit hétéropolysaccharide.
4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel on mélange et on cisaille en continu le concentré et le milieu aqueux salin.
5. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel la viscosité de la solution obtenue après cisaillement est de 2 à 400 mPa.s à un taux de cisaillement de $7,5\text{ s}^{-1}$ et à 30°C .



heteropolysaccharide. The machine was operated at a shearing rate of $43,000\text{ s}^{-1}$, a throughput of $1.6\text{ m}^3/\text{h}$ and a power input of 1.18 kWh/m^3 . After one pass the filterability of the solution was 75 s/l and the viscosity was 11.0 mPa.s at 7.5 s^{-1} and 30°C .

From the above Examples it is apparent that xanthan gum can hardly be dissolved in high salinity brines and no useful product is obtained thereby, whereas heteropolysaccharide I can easily be dissolved at a power input below 10 kWh/m^3 yielding solutions with excellent filterability and viscosity properties. Use of an in line wet comminution machine yields effective solutions at the lowest power input.

Claims

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1. Process for the preparation of an aqueous solution of a heteropolysaccharide comprising glucose, galactose, pyruvic and succinic acid and obtained by cultivation of a microorganism, in which process a concentrate of said heteropolysaccharide is mixed with a saline aqueous medium containing from 12 to 30%w of at least one salt, and the mixture obtained is sheared at a temperature ranging from 20 to 100°C , at a pressure in the range 1×10^5 to $15 \times 10^5\text{ Pa}$, at a shear rate from 10,000 to $200,000\text{ s}^{-1}$ and at a power input of 0.5 to 10 kWh/m^3 .
2. Process according to claim 1, in which the heteropolysaccharide is obtained by cultivation of Pseudomonas sp. NCIB 11264, Pseudomonas sp. NCIB 11592 or microorganism NCIB 11883, or mutants thereof.
3. Process according to claim 1 or 2, in which the heteropolysaccharide concentrate is an aqueous concentrate containing 4 to 15%w of said heteropolysaccharide.
4. Process according to any one of claims 1-3, in which the concentrate and the saline aqueous medium are mixed and sheared in a continuous manner.
5. Process according to any one of claims 1-4, in which the viscosity of the solution obtained after shearing ranges from 2 to 400 mPa.s at a shear rate of 7.5 s^{-1} and at 30°C .
6. Process according to any one of claim 1-5, in which the solution contains from 100 to 2000 ppmw of heteropolysaccharide.
7. Use of an aqueous solution of heteropolysaccharide prepared by a process according to any one of claims 1-6 in the production of oil from an underground oil-containing reservoir.

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Revendications

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1. Procédé de préparation d'une solution aqueuse d'un hétéropolysaccharide comprenant du glucose, du galactose, de l'acide pyruvique et de l'acide succinique qu'on obtient par culture d'un microorganisme, procédé selon lequel on mélange un concentré dudit hétéropolysaccharide avec un fluide aqueux salin contenant de 12 à 30% en poids d'au moins un sel, et on cisaille le mélange obtenu à une température comprise entre 20 et 100°C , sous une pression comprise entre 1×10^5 et $15 \times 10^5\text{ Pa}$, à un taux de cisaillement de 10.000 à 200.000 s^{-1} et avec un apport d'énergie de 0,5 à 10 kWh/m^3 .
2. Procédé selon la revendication 1, dans lequel on obtient l'hétéropolysaccharide par culture de Pseudomonas sp NCIB 11264, Pseudomonas sp NCIB 11592 ou du microorganisme NCIB 11883 ou des mutants de ceux-ci.
3. Procédé selon la revendication 1 ou 2, dans lequel le concentré d'hétéropolysaccharide est un concentré aqueux contenant de 4 à 15% en poids dudit hétéropolysaccharide.
4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel on mélange et on cisaille en continu le concentré et le milieu aqueux salin.
5. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel la viscosité de la solution obtenue après cisaillement est de 2 à 400 mPa.s à un taux de cisaillement de $7,5\text{ s}^{-1}$ et à 30°C .

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6. Procédé selon l'une quelconque des revendications 1 à 5, dans lequel la solution contient de 100 à 2000 ppm en poids d'hétéropolysaccharide.
7. Utilisation d'une solution aqueuse d'hétéropolysaccharide préparée par un procédé selon l'une quelconque des revendications 1 à 6 dans la production d'huile à partir d'un réservoir souterrain contenant l'huile.

Patentansprüche

1. Verfahren zur Herstellung einer wäßrigen Lösung eines Heteropolysaccharides, welches Glukose, Galaktose, Brenztraubensäure und Bernsteinsäure enthält und durch Kultivierung eines Mikroorganismus erhalten wird, in welchem Verfahren ein Konzentrat des genannten Heteropolysaccharides mit einem salzhaltigen wäßrigen Medium, welches 12 bis 30 Gew.-% von mindestens einem Salz beinhaltet, vermischt wird und das erhaltene Gemisch einer Schereinwirkung unterworfen wird, bei einer Temperatur, welche von 20 bis 100 °C reicht, bei einem Druck im Bereich von 1×10^5 bis 5×10^5 Pa, bei einer Schergeschwindigkeit von 10.000 bis 200.000 s^{-1} und bei einer Leistungsaufnahme von 0,5 bis 10 kWh/m³.
2. Verfahren nach Anspruch 1, worin das Heteropolysaccharid durch Kultivierung von *Pseudomonas* sp. NCIB 11264, *Pseudomonas* sp. NCIB 11592 oder Mikroorganismus NCIB 11883 oder von Mutanten hiervon erhalten wird.
3. Verfahren nach Anspruch 1 oder 2, worin das Heteropolysaccharidkonzentrat ein wäßriges Konzentrat ist, welches 4 bis 15 Gew.-% des genannten Heteropolysaccharides enthält.
4. Verfahren nach einem der Ansprüche 1 bis 3, worin das Konzentrat und das salzhaltige wäßrige Medium in kontinuierlicher Weise vermischt und einer Schereinwirkung unterworfen werden.
5. Verfahren nach einem der Ansprüche 1 bis 4, worin die Viskosität der nach dem Scheren erhaltenen Lösung von 2 bis 400 mPa.s bei einer Schergeschwindigkeit von 7,5 s^{-1} und bei 30 °C reicht.
6. Verfahren nach einem der Ansprüche 1 bis 5, worin die Lösung 100 bis 2.000 ppm, bezogen auf das Gewicht, an Heteropolysaccharid enthält.
7. Verwendung einer wäßrigen Lösung von Heteropolysaccharid, welche nach einem Verfahren gemäß einem der Ansprüche 1 bis 6 hergestellt wurde, bei der Gewinnung von Öl aus unterirdischen ölenthaltenden Lagerstätten.