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(54) Titre : MELANGES POLYMERES COMME INHIBITEURS DE DEPOT DANS DES SYSTEMES A CIRCULATION
D'EAU

(54) Title: POLYMER MIXTURES AS DEPOSIT INHIBITORS IN WATER-BEARING SYSTEMS

(57) **Abrégé/Abstract:**

The invention relates to a polymer blend in solid or aqueous form containing, relative to the polymer content, (A) 5 to 95 wt% of a water-soluble or water-dispersible polymer with an average molecular weight of 1000 to 20000 g/mol consisting of (a1) 20 to 80 wt% of at least one monomer, selected from the group consisting of C₂-C₈ olefins, allyl alcohol, isoprenol, C₁-C₄ alkyl vinyl ethers and vinyl esters of C₁-C₄ monocarboxylic acids, (a2) 20 to 80 wt% of at least one monoethylenically unsaturated C₃-C₈ carboxylic acid, an anhydride or a salt thereof, (a3) 0 to 50 wt% of one or more monomers containing sulphonic acid groups, (B) 5 to 95 wt% of a water-soluble or water-dispersible polymer with an average molecular weight of 1000 to 50000 g/mol consisting of (b1) 30 to 100 wt% of at least one monoethylenically unsaturated C₃-C₈ carboxylic acid, an anhydride or a salt thereof, (b2) 0 to 70 wt% of one or more monomers containing sulphonic acid groups, (b3) 0 to 70 wt% of at least one non-ionic monomer of formula (I), H₂C=C(R¹)(CH₂)_xO[R²-O]_o-R³, wherein R¹ represents hydrogen or methyl, R² represents the same or different, linear or branched C₂-C₆ alkylene groups, which can be arranged block-wise or statistically, and R³ represents hydrogen or a straight-chain or branched C₁-C₄ alkyl group, x representing 0, 1 or 2 and o for a number between 3 and 50.



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(54) Title: POLYMER BLENDS AS COATING INHIBITORS IN WATER-CARRYING SYSTEMS

(54) Bezeichnung : POLYMERMISCHUNGEN ALS BELAGSINHIBITOREN IN WASSERFÜHRENDEN SYSTEMEN

(57) Abstract: The invention relates to a polymer blend in solid or aqueous form containing, relative to the polymer content, (A) 5 to 95 wt% of a water-soluble or water-dispersible polymer with an average molecular weight of 1000 to 20000 g/mol consisting of (a1) 20 to 80 wt% of at least one monomer, selected from the group consisting of C₂-C₈ olefins, allyl alcohol, isoprenol, C₁-C₄ alkyl vinyl ethers and vinyl esters of C₁-C₄ monocarboxylic acids, (a2) 20 to 80 wt% of at least one monoethylenically unsaturated C₃-C₈ carboxylic acid, an anhydride or a salt thereof, (a3) 0 to 50 wt% of one or more monomers containing sulphonic acid groups, (B) 5 to 95 wt% of a water-soluble or water-dispersible polymer with an average molecular weight of 1000 to 50000 g/mol consisting of (b1) 30 to 100 wt% of at least one monoethylenically unsaturated C₃-C₈ carboxylic acid, an anhydride or a salt thereof, (b2) 0 to 70 wt% of one or more monomers containing sulphonic acid groups, (b3) 0 to 70 wt% of at least one non-ionic monomer of formula (I), H₂C=C(R¹)(CH₂)_xO[R²-O]_o-R³, wherein R¹ represents hydrogen or methyl, R² represents the same or different, linear or branched C₂-C₆ alkylene groups, which can be arranged block-wise or statistically, and R³ represents hydrogen or a straight-chain or branched C₁-C₄ alkyl group, x representing 0, 1 or 2 and o for a number between 3 and 50.(57) Zusammenfassung: Polymermischung in fester oder wässriger Form, enthaltend, bezogen auf den Polymeranteil, (A) 5 bis 95 Gew.-% eines wasserlöslichen bzw. wasserdispergierbaren Polymeren mit einem gewichtsmittleren Molekulargewicht von 1000 bis 20000 g/mol aus (a1) 20 bis 80 Gew.-% mindestens eines Monomeren ausgewählt aus der Gruppe bestehend aus C₂- bis C₈-Olefinen, Allylalkohol, Isoprenol, C₁- bis C₄-Alkylvinylethern und Vinylestern von C₁- bis C₄-Monocarbonsäuren, (a2) 20 bis 80 Gew.-% mindestens einer monoethylenisch ungesättigten C₃- bis C₈-Carbonsäure, eines Anhydrids oder Salzes derselben, (a3) 0 bis 50 Gew.-% einer oder mehrerer Sulfonsäuregruppen enthaltender Monomere, (B) 5 bis 95 Gew.-% eines wasserlöslichen bzw. wasserdispergierbaren Polymeren mit einem gewichtsmittleren Molekulargewicht von 1000 bis 50000 g/mol aus (b1) 30 bis 100 Gew.-% mindestens einer monoethylenisch ungesättigten C₃- bis C₈-Carbonsäure, eines Anhydrids oder Salzes derselben, (b2) 0 bis 70 Gew.-% eines oder mehrerer Sulfonsäuregruppen enthaltender Monomere, (b3) 0 bis 70 Gew.-% mindestens eines nichtionischen Monomers der Formel (I), H₂C=C(R¹)(CH₂)_xO[R²-O]_o-R³, in der R¹ für Wasserstoff oder Methyl, R² für gleiche oder verschiedene, lineare oder verzweigte C₂-C₆-Alkylreste, die blockweise oder statistisch angeordnet sein können, und R³ für Wasserstoff oder einen geradkettigen oder verzweigten C₁-C₄-Alkylrest, x für 0, 1 oder 2 und o für eine Zahl von 3 bis 50 stehen.

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Polymer mixtures as deposit inhibitors in water-bearing systems

Description

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The invention relates to polymer mixtures as deposit inhibitors for inhibiting the precipitation and sedimentation of calcium salts and magnesium salts in water-bearing systems.

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The solubility of most substances in water is restricted. In particular, in industrial water treatment, the prevention of mineral sediments in water-bearing systems is an essential task. Inorganic substances and salts such as calcium carbonate, magnesium carbonate, magnesium hydroxide, calcium sulfate and barium sulfate, and calcium phosphate have a low solubility in water. If these dissolved components are concentrated in aqueous systems (thickening), the solubility product is exceeded with the consequence that these substances precipitate out and cause sediments. The solubility of the substances is, in addition, dependent on the temperature and the pH. In particular, many substances such as calcium carbonate, calcium sulfate or magnesium hydroxide exhibit an inverse solubility, i.e. their solubility decreases with increasing temperature. This leads to high process temperatures frequently being the cause of unwanted precipitates and formation of deposits in cooling and boiler feed water systems on heat-exchange surfaces or in pipelines.

25 Precipitates and sediments of inorganic substances and salts in water-bearing systems may only be removed again with great effort. Each mechanical and chemical cleaning is costly and time-consuming and inescapably leads to production failures.

30 Not only in cooling and boiler feed water systems are attempts made to prevent the formation of calcium carbonate deposits, calcium sulfate deposits, magnesium hydroxide deposits and other salt deposits. Also in seawater desalination by distillation and by membrane methods such as reverse osmosis or electrodialysis, efforts are made to prevent formation of these solid deposits. In particular in thermal seawater desalination

plants, both effects, namely firstly concentration by evaporation of water, and, secondly, high processing temperatures, play an important role.

The productivity of desalination plants is limited in this case by the upper processing
5 temperature. It is desirable to operate seawater desalination plants at an evaporation
temperature as high as possible in order to achieve a process efficiency as high as
possible and to minimize the energy required for producing fresh water. For
characterization of the process efficiency, the characteristic kWh/m³ of water is used. This
characteristic can be minimized by process temperatures as high as possible for the
10 multistage expansion evaporation process and the multiple effect evaporation process.
The maximum process temperature in these processes is limited, primarily, by the deposit
formation which increases continuously with increasing temperature. It is known that, in
particular, the sedimentation of basic magnesium salts such as magnesium hydroxide
(brucite) and magnesium carbonate hydroxide (hydromagnesite), and also calcium
15 carbonate and calcium sulfate play a critical role in thermal desalination plants.

It is known that low-molecular-weight polyacrylic acids and salts thereof produced by
means of free-radical polymerization are employed as deposit inhibitors in industrial water
treatment and in seawater desalination owing to the dispersant properties, and properties
20 inhibiting crystal growth, thereof. For a good activity, the mean molecular weight (M_w) of
these polymers should be < 50 000 g/mol. Frequently, polyacrylic acids having M_w
< 10 000 g/mol are described as particularly effective. A disadvantage of these polymers is
their sensitivity to hardness rising with increasing temperature, i.e. the risk that the
polymers precipitate as Ca or Mg polyacrylates increases. In addition, the polyacrylic acids
25 have only a very low inhibitory activity against sediments of brucite or hydromagnesite.

In addition, it is known that copolymers comprising sulfonic acid groups act as deposit
inhibitors, in particular for avoiding deposits of calcium phosphates and calcium
phosphonates. A disadvantage of these polymers is their limited activity for avoiding
30 CaCO₃ precipitates.

In order to compensate for the disadvantages of certain polymers, frequently mixtures of a plurality of different polymers or copolymers are used. In the case of polymer mixtures, a synergistic activity is observed from time to time.

- 5 EP 388 836 discloses a mixture of a hydrolyzed polymaleic anhydride and a hydrolyzed copolymer of maleic anhydride and ethylenically unsaturated copolymers having a molecular weight from 400 to 800 g/mol for inhibiting scale sediments in aqueous systems. Ethylenically unsaturated comonomers mentioned are acrylic acid, methacrylic acid, crotonic acid, itaconic acid, aconitic acid, itaconic anhydride, ethyl acrylate, methyl
10 methacrylate, acrylonitrile, acrylamide, vinyl acetate, styrene, alpha-methylstyrene, vinylsulfonic acid, 2-acrylamido-2-methylpropanesulfonic acid, methyl vinyl ketone, acrolein, ethylene and propylene.

- US 2009/0101587 A1 discloses a deposit-inhibiting composition comprising a copolymer of
15 acrylic acid and 2-acrylamido-2-methylpropanesulfonic acid and an oligomeric phosphinosuccinic acid.

- US 5263541 discloses a mixture of polyvinyl sulfonate and polyacrylic acid as calcium sulfate deposit inhibitor.
20

- DE 41 07 322 describes a composition of a hydrolyzed homopolymer of maleic anhydride having a weight-average molecular weight of 400 to 800 and a carboxyl-comprising acrylic polymer having a molecular weight of 800 to 9500 as deposit inhibitor. Acrylic polymers mentioned are polyacrylic acid and polymethacrylic acid, and also copolymers of acrylic
25 acid or methacrylic acid with a vinyl carboxylate or styrene.

- US 4,936,987 describes a mixture of a copolymer of acrylic acid or methacrylic acid and 2-acrylamido-2-methylpropylsulfonic acid or 2-methacrylamido-2-methylpropylsulfonic acid and at least one further component. Further components mentioned are, inter alia,
30 homopolymers of maleic acid or acrylic acid, and also copolymers of acrylamide and acrylate, copolymers of acrylic acid and 2-hydroxypropyl acrylate, or copolymers of maleic acid and sulfonated styrene.

JP 06154789 describes a composition of hydrolyzed copolymer of maleic anhydride and isobutene and hydrolyzed copolymer of maleic anhydride and aliphatic diene as deposit inhibitor. The inhibitor acts primarily against silicate and calcium carbonate deposits.

- 5 It is an object of the invention to provide compositions having an improved deposit-inhibiting activity which effectively prevent, in particular, precipitation and deposition of calcium carbonate, calcium sulfate and basic magnesium salts in the water-bearing systems.
- 10 The object is achieved by a polymer mixture in solid or aqueous form comprising, based on the polymer fraction,
- (A) 5 to 95% by weight of a water-soluble or water-dispersible polymer having a weight-average molecular weight of 1000 to 20 000 g/mol of
- 15 (a1) 20 to 80% by weight of at least one monomer selected from the group consisting of C₂ to C₈ olefins, allyl alcohol, isoprenol, C₁ to C₄ alkyl vinyl ethers and vinyl esters of C₁ to C₄ monocarboxylic acids,
- 20 (a2) 20 to 80% by weight of at least one monoethylenically unsaturated C₃ to C₈ carboxylic acid, an anhydride or salt of same,
- (a3) 0 to 50% by weight of one or more monomers comprising sulfonic acid groups,
- 25 (B) 5 to 95% by weight of a water-soluble or water-dispersible polymer having a weight-average molecular weight of 1000 to 50 000 g/mol of
- (b1) 30 to 100% by weight of at least one monoethylenically unsaturated C₃ to
- 30 C₈ carboxylic acid, an anhydride or salt of same,
- (b2) 0 to 70% by weight of one or more monomers comprising sulfonic acid groups,

(b3) 0 to 70% by weight of one or more nonionic monomers of the formula (I)



5

where R^1 is hydrogen or methyl, R^2 is identical or different, linear or branched, C_2 - C_6 alkylene radicals, which can be arranged in blocks or randomly, and R^3 is hydrogen or a straight-chain or branched C_1 - C_4 alkyl radical, x is 0, 1 or 2, and o is a number from 3 to 50.

10

It has been found that mixtures of the polymers (A) and (B) have a higher activity in the inhibition of sediments of calcium carbonate, calcium sulfate and basic magnesium salts than the same amount of only one of the polymers (A) or (B) alone. One or more different polymers (A) can be mixed with one or more different polymers (B).

15

The polymer mixture according to the invention comprises 5 to 95% by weight of a water-soluble or water-dispersible polymer (A) of 20 to 80% by weight of at least one monomer (a1) selected from the group consisting of C_2 to C_8 olefins, allyl alcohol, isoprenol, C_1 to C_4 alkyl vinyl ethers and vinyl esters of C_1 to C_4 monocarboxylic acids, and 20 to 80% by weight of at least one monomer (a2) selected from unsaturated C_3 to C_8 carboxylic acids, anhydrides or salts of same, and also, optionally, 0 to 50% by weight of one or more monomers (a3) comprising sulfonic acid groups.

20

The polymer mixture comprises 5 to 95% by weight of a water-soluble or water-dispersible polymer (B) of 30 to 100% by weight of at least one monomer (b1) selected from monoethylenically unsaturated C_3 to C_8 carboxylic acids, anhydrides or salts of same, and also, optionally, 0 to 70% by weight of one or more monomers (b2) comprising sulfonic acid groups.

25

Suitable C_2 to C_8 olefins which can be used as monomer (a1) are, for example, ethylene, propylene, n-butene, isobutene, 1-pentene, 1-hexene, 1-heptene and diisobutene, preferably isobutene and diisobutene.

30

Suitable alkyl vinyl ethers which can be used as monomer (a1) comprise 1 to 4 carbon atoms in the alkyl chain. Examples are vinyl methyl ether, vinyl ethyl ether, vinyl n-propyl ether, vinyl isopropyl ether, vinyl n-butyl ether and vinyl isobutyl ether.

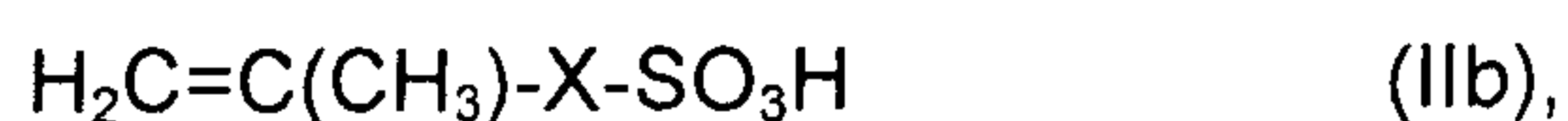
- 5 Vinyl esters of C₁ to C₄ monocarboxylic acids which can be used as monomer (a1) are, for example, vinyl formate, vinyl acetate, vinyl propionate and vinyl butyrate.

Preferred monomers (a1) are isobutene, diisobutene, vinyl acetate, vinyl methyl ether allyl alcohol and isoprenol. Particular preference is given to isobutene, diisobutene and
10 isoprenol.

Suitable monoethylenically unsaturated C₃-C₈ carboxylic acids which can be used as monomer (a2) and (b1) are, for example, acrylic acid, methacrylic acid, ethacrylic acid, vinyl acetic acid, allyl acetic acid, crotonic acid, maleic acid, fumaric acid, mesaconic acid
15 and itaconic acid and also water-soluble salts thereof. If said unsaturated C₃-C₈ carboxylic acids can form anhydrides, these anhydrides are also suitable as monomer (a1), for example maleic anhydride, itaconic anhydride and methacrylic anhydride.

Preferred monoethylenically unsaturated C₃-C₈ carboxylic acids are acrylic acid, methacrylic acid, maleic acid and fumaric acid and also anhydrides and water-soluble salts thereof. These are preferred both as monomer (a2) and monomer (b1). Water-soluble salts are, in particular, the sodium and potassium salts of the acids.
20

Monomers comprising sulfonic acid groups (a3) and (b2) are preferably those of the formulae (IIa) and (IIb)
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where X is an optionally present spacer group which can be selected from -(CH₂)_n- where n = 0 to 4, -C₆H₄-, -CH₂-O-C₆H₄-, -C(O)-NH-C(CH₃)₂-, -C(O)-NH-CH(CH₂CH₃)-, -C(O)NH-

CH(CH₃)CH₂-, -C(O)NH-C(CH₃)₂CH₂-, -C(O)NH-CH₂CH(OH)CH₂-, -C(O)NH-CH₂-, -C(O)NH-CH₂CH₂- and -C(O)NH-CH₂CH₂CH₂-.

Particularly preferred monomers comprising sulfonic acid groups are in this case

5 1-acrylamido-1-propanesulfonic acid (X = -C(O)NH-CH(CH₂CH₃)- in formula IIa),
 2-acrylamido-2-propanesulfonic acid (X = -C(O)NH-CH(CH₃)CH₂- in formula IIa),
 2-acrylamido-2-methylpropanesulfonic acid (AMPS, X = -C(O)NH-C(CH₃)₂CH₂- in formula IIa),
 2-methacrylamido-2-methylpropanesulfonic acid (X = -C(O)NH-C(CH₃)₂CH₂- in formula IIb),
 3-methacrylamido-2-hydroxypropanesulfonic acid (X = -C(O)NH-CH₂CH(OH)CH₂- in formula IIb), allylsulfonic acid (X = CH₂ in formula IIa),
 10 methallylsulfonic acid (X = CH₂ in formula IIb), allyloxybenzenesulfonic acid (X = -CH₂-O-C₆H₄- in formula IIa), methallyloxybenzenesulfonic acid (X = -CH₂-O-C₆H₄- in formula IIb),
 2-hydroxy-3-(2-propenyloxy)propanesulfonic acid, 2-methyl-2-propene-1-sulfonic acid (X = CH₂ in formula IIb), styrenesulfonic acid (X = C₆H₄ in formula IIa), vinylsulfonic acid (X not present in formula IIa), 3-sulfopropyl acrylate (X = -C(O)O-CH₂CH₂CH₂- in formula IIa), 2-sulfoethyl methacrylate (X = -C(O)O-CH₂CH₂- in formula IIb), 3-sulfopropyl methacrylate (X = -C(O)O-CH₂CH₂CH₂- in formula IIb), sulfomethacrylamide (X = -C(O)NH- in formula IIb), sulfomethylmethacrylamide (X = -C(O)NH-CH₂- in formula IIb), and also salts of said acids. Suitable salts are generally water-soluble salts, preferably the sodium, potassium and ammonium salts of said acids.

20

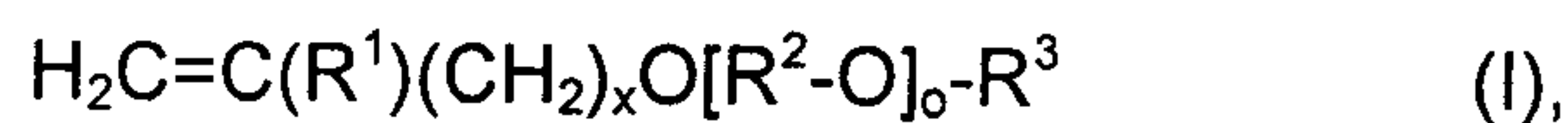
Particular preference is given to 1-acrylamidopropanesulfonic acid, 2-acrylamido-2-propanesulfonic acid, 2-acrylamido-2-methylpropanesulfonic acid (AMPS), 2-methacrylamido-2-methylpropanesulfonic acid, 3-methacrylamido-2-hydroxypropanesulfonic acid, 2-hydroxy-3-(2-propenyloxy)propanesulfonic acid, 2-sulfoethyl methacrylate, styrenesulfonic acid, vinylsulfonic acid, allylsulfonic acid (ALS) and methallylsulfonic acid, and also salts of said acids. These are preferred both as monomer (a3) and also (b2).

25

Very particularly preferred monomers comprising sulfonic acid groups are 2-acrylamido-2-methylpropanesulfonic acid (AMPS) and allylsulfonic acid, and also water-soluble salts thereof, in particular sodium, potassium and ammonium salts thereof. These are preferred both as monomer (a3) and (b2).

30

As component (b3), the copolymer comprises 0 to 70% by weight of at least one nonionic monomer of the formula (I)



5

where R^1 is hydrogen or methyl, R^2 is identical or different $\text{C}_2\text{-C}_6$ alkylene radicals, which can be linear or branched and arranged in blocks and/or randomly, and R^3 is hydrogen or a straight-chain or branched $\text{C}_1\text{-C}_4$ alkyl radical, x is 0, 1 or 2, and o is a natural number from 3 to 50.

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The alkylene radicals can also be arranged in blocks and randomly, that is to say in one or more blocks of identical alkylene oxide radicals in blocks and, in addition, randomly in one or more blocks of two or more different alkylene oxide radicals. This is also included by the wording "arranged in blocks or randomly".

15

Preferred nonionic monomers (b3) are those based on allyl alcohol ($\text{R}^1 = \text{H}$; $x = 1$) and isoprenol ($\text{R}^1 = \text{methyl}$; $x = 2$).

The nonionic monomer (b3) preferably comprises on average 8 to 40, particularly preferably 10 to 30, especially 10 to 25, alkylene oxide units. The index o in the formula (I) relates to the median number of alkylene oxide units.

Preferred alkylene oxide units $\text{R}^2\text{-O}$ are ethylene oxide, 1,2-propylene oxide and 1,2-butylene oxide, particular preference is given to ethylene oxide and 1,2-propylene oxide.

25

In a special embodiment, the nonionic monomers (b3) only comprise ethylene oxide units. In a further special embodiment, the nonionic monomers (b3) comprise ethylene oxide and 1,2-propylene oxide units which can be arranged in blocks or randomly.

30

Preferably, R^3 is hydrogen or methyl.

Generally, the weight-average molecular weight of the copolymers (A) is 1000 to 20 000 g/mol, preferably 1500 to 15 000 g/mol, and particularly preferably 2000 to 10 000 g/mol, and in particular 2000 to 8000 g/mol.

- 5 The molecular weight is determined by means of gel-permeation chromatography in comparison with polyacrylic acid standards.

Generally, the polydispersity index of the polymers (A) M_w/M_n is ≤ 3.0 , preferably ≤ 2.5 .

- 10 The polymers (A) are preferably binary copolymers or terpolymers. If they are binary copolymers, they preferably comprise 20 to 60% by weight of monomer (a1) and 40 to 80% by weight of monomer (a2), particularly preferably 25 to 50% by weight of monomer (a1) and 50 to 75% by weight of monomer (a2).

- If they are terpolymers, they preferably comprise 25 to 50% by weight of monomer (a1), 30
15 to 60% by weight of monomer (a2) and 10 to 30% by weight of monomer (a3).

- A plurality of different monomers (a1) and/or a plurality of different monomers (a2) can also be present in the polymers A. For example, terpolymers and quaterpolymers can comprise only monomers (a1) and (a2), preferably in the amounts stated above for binary
20 copolymers.

In a preferred embodiment of the invention, polymer (A) is a copolymer of isobutene and maleic acid, preferably in the quantitative ratios stated above for binary copolymers.

- 25 In a further preferred embodiment of the invention, polymer (A) is a copolymer of isoprenol and maleic acid, preferably in the quantitative ratios cited above for binary copolymers.

- In a further embodiment of the invention, polymer (A) is a terpolymer of isoprenol, maleic acid and 2-acrylamido-2-methylpropanesulfonic acid, preferably in the quantitative ratios
30 cited above for terpolymers. In a further preferred embodiment, allylsulfonic acid is used instead of 2-acrylamido-2-methylpropanesulfonic acid.

In a further embodiment of the invention, polymer (A) is a terpolymer of isoprenol, maleic acid and acrylic acid, preferably in the quantitative ratios cited above.

5 The polymers (B) are homopolymers or copolymers. Copolymers can comprise monomers (b1), monomers (b1) and (b2), monomers (b1) and (b3), and monomers (b1), (b2) and (b3). If copolymers of the monomers (b1) and (b2) are concerned, they preferably comprise 50 to 90% by weight of monomers (b1) and 10 to 50% by weight of monomers (b2), particularly preferably 60 to 85% by weight of monomers (b1) and 15 to 40% by weight of monomers (b2).

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If copolymers of the monomers (b1) and (b3) are concerned, they preferably comprise 50 to 95% by weight of monomers (b1) and 5 to 50% by weight of monomers (b3), particularly preferably 60 to 90% by weight of monomers (b1) and 10 to 40% by weight of monomers (b3).

15

If copolymers of the monomers (b1), (b2) and (b3) are concerned, they preferably comprise 30 to 80% by weight of monomers (b1), 10 to 50% by weight of monomers (b2) and 5 to 50% by weight of monomers (b3), particularly preferably 40 to 75% by weight of monomers (b1), 15 to 40% by weight of monomers (b2) and 5 to 40% by weight of monomers (b3). Preference is given to binary copolymers, but they can also be terpolymers.

20

In a preferred embodiment of the invention, the polymer (B) is an acrylic acid homopolymer.

25

In a further preferred embodiment of the invention, polymer (B) is a copolymer of acrylic acid and 2-acrylamido-2-methylpropanesulfonic acid, preferably in the quantitative ratios cited above.

30

In a further preferred embodiment of the invention, polymer (B) is a copolymer of acrylic acid and allylsulfonic acid, preferably in the quantitative ratios cited above.

Generally, the weight-average molecular weight of the polymers (B) is 1000 to 50 000 g/mol, preferably 1000 to 30 000 g/mol and particularly preferably 1500 to 20 000 g/mol, and in particular 1500 to 10 000 g/mol.

- 5 The molecular weight is determined by means of gel-permeation chromatography in comparison with polyacrylic acid standards.

Generally, the polydispersity index of the polymers (B) M_w/M_n is ≤ 2.5 , preferably ≤ 2.0 .

- 10 The present invention also relates to compositions comprising

(A) 3 to 95% by weight of the water-soluble or water-dispersible polymers having a weight-average molecular weight of 1000 to 20 000 g/mol of

15 (a1) 20 to 80% by weight of at least one monomer selected from the group consisting of C_2 to C_8 olefins, allyl alcohol, isoprenol, C_1 to C_4 alkyl vinyl ethers and vinyl esters of C_1 to C_4 monocarboxylic acids,

20 (a2) 20 to 80% by weight of at least one monoethylenically unsaturated C_3 to C_8 carboxylic acid, an anhydride or salt of same,

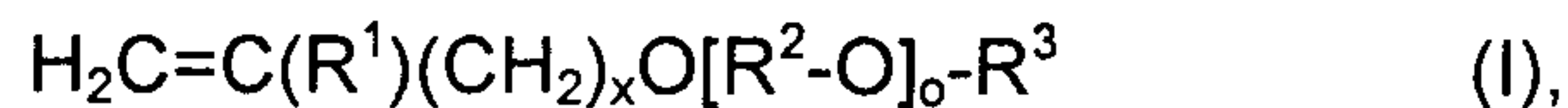
(a3) 0 to 50% by weight of one or more monomers comprising sulfonic acid groups,

25 (B) 3 to 95% by weight of the water-soluble or water-dispersible polymer having a weight-average molecular weight of 1000 g/mol to 50 000 g/mol of

(b1) 30 to 100% by weight of at least one monoethylenically unsaturated C_3 to C_8 carboxylic acid, an anhydride or salt of same,

30 (b2) 0 to 70% by weight of one or more monomers comprising sulfonic acid groups,

(b3) 0 to 70% by weight of one or more nonionic monomers of the formula (I)



- 5 where R^1 is hydrogen or methyl, R^2 is identical or different, linear or branched, C_2 - C_6 alkylene radicals, which can be arranged in blocks or randomly, and R^3 is hydrogen or a straight-chain or branched C_1 - C_4 alkyl radical, x is 0, 1 or 2, and o is a number from 3 to 50,
- 10 (C) 0 to 80% by weight of phosphonates,
- (D) 0 to 90% by weight of water;
- 15 (E) 0 to 50% by weight of additives such as polyphosphates, zinc salts, molybdate salts, organic corrosion inhibitors, biocides, complexing agents, surfactants or antifoams.

The weight ratio of polymers (A):(B) is generally from 1:20 to 20:1.

- 20 The compositions according to the invention can optionally comprise up to 80% by weight phosphonates (C). Phosphonates can additionally support the deposit-inhibiting activity of the polymers. In addition, they act as corrosion inhibitors.

25 Examples of phosphonates are 1-hydroxyethane-1,1-diphosphonic acid (HEDP), 2-phosphonobutane-1,2,4-tricarboxylic acid (PBTC), aminotrimethylenephosphonic acid (ATMP), diethylenetriaminepenta(methylenephosphonic acid) (DTPMP) and ethylenediamine-tetra(methylenephosphonic acid) (EDTMP), and also the water-soluble salts thereof, in particular the sodium, potassium and ammonium salts thereof.

- 30 In addition, the compositions according to the invention can comprise up to 90% by weight of water.

In addition, the formulations can, in addition to the polymer mixtures according to the invention, optionally the phosphonates, and optionally water, according to requirements, also comprise up to 50% by weight of further additives (E) such as polyphosphates, zinc salts, molybdate salts, organic corrosion inhibitors such as benzotriazole, tolyltriazole, benzimidazole or ethynyl carbinol alkoxylates, biocides, complexing agents and/or surfactants.

The polymer mixtures of polymers (A) and (B) are generally produced by mixing the respective polymer solutions in stirred systems such as, e.g., in stirred tanks, by pneumatic circulation in containers, by circulation using pumps or by forced flow in pipes. Internals in the stirred systems, termed flow baffles, can accelerate the mixing operation. By installing fixed mixing elements in pipelines such as metal sheet lamellae, spirals or rigids, or mixing nozzles, the mixing operation can likewise be accelerated. The choice of the mixer or the mixing process depends on the respective requirements, in particular the viscosities and shear strengths of the polymer solutions that are to be mixed. Solid polymer mixtures can be produced by spray drying and spray granulation of the aqueous polymer mixtures or by mixing the solid polymers by means of rotating mixing drums, blade mixers, screw mixers, fluidized-bed mixers or air-shock mixers. The invention relates to both solid polymer mixtures, for example obtained by spray drying or spray granulation, and aqueous polymer mixtures. The water content of aqueous polymer mixtures is generally up to 90% by weight, preferably up to 70% by weight, particularly preferably up to 50% by weight.

The invention also relates to the use of the polymer mixtures and compositions as deposit inhibitors for inhibiting the precipitation and sedimentation of calcium salts and magnesium salts in water-bearing systems. Calcium salts the precipitation of which is inhibited are generally calcium carbonate, calcium sulfate, calcium phosphonates and calcium phosphates, in particular calcium carbonate and calcium sulfate. Magnesium salts the precipitation of which is inhibited are generally basic magnesium salts such as hydromagnesite and brucite.

Water-bearing systems in which the polymer mixtures are preferably employed are seawater desalination plants, brackish water desalination plants, cooling water systems and boiler feed water systems.

- 5 Surprisingly, it has also been found that the polymer mixtures according to the invention, owing to their dispersive properties and properties stabilizing Fe(III) ions, are outstandingly suitable for preventing iron-comprising sediments in water-bearing systems.

10 The invention therefore further relates to the employment of the polymer mixtures and compositions as deposit inhibitors for inhibiting the precipitation and sedimentation of iron-comprising salts and compounds. In particular, sedimentation of iron oxides and iron oxide hydrates (iron hydroxides) are prevented.

15 Generally, the mixtures according to the invention are added to the water-bearing systems in amounts from 0.1 mg/l to 100 mg/l. The optimum dosage depends on the requirements of the respective application or the operating conditions of the respective process. For instance, in the thermal desalination of seawater, the mixtures are preferably used in concentrations from 0.5 mg/l to 10 mg/l. In industrial cooling circuits or boiler feed water systems, dosages up to 100 mg/l are employed. Frequently, water analyses are carried
20 out in order to determine the proportion of deposit-forming salts and thereby the optimum dosage.

The invention will be described in more detail by the examples hereinafter.

25 Examples

The median molecular weights were determined by means of GPC.

30 Instrument: Waters Alliance 2690 with UV-detector (Waters 2487) and RI detector (Waters 2410)
Columns: Shodex OHpak SB 804HQ and 802.5HQ
(PHM gel, 8 x 300 mm, pH 4.0 to 7.5)

Eluent: 0.05 M aqueous ammonium formate/methanol mixture = 80:20 (parts by volume)
Flow rate: 0.5 ml/min
Temperature: 50°C
5 Injection: 50 to 100 µl
Detection: RI and UV

Molecular weights of the polymers were determined relative to polyacrylic acid standards from Varian Inc. The molecular weight distribution curves of the polyacrylic acid standards
10 were determined by light scattering. The masses of the polyacrylic acid standards were 115 000, 47 500, 28 000, 16 000, 7500, 4500, 4100, 2925 and 1250 g/mol.

Polymers 2, 3, 6, 7, 12 and 14 are produced by free-radical polymerization of the monomers in water using sodium peroxodisulfate as initiator and sodium hypophosphite
15 (polymers 2 and 7) and sodium bisulfite (polymers 3, 6, 12 and 14) as molecular weight modifier.

Polymers 4, 5, 8, 9 and 13 are produced by free-radical polymerization of the monomers using a redox system of hydrogen peroxide, iron(II) sulfate and sodium
20 hydroxymethanesulfinate as initiator and mercaptoethanol as chain-transfer agent.

Polymers 1, 10 and 11 are produced by free-radical polymerization of maleic anhydride with the respective comonomers in o-xylene or toluene using t-butyl perpivalate as initiator. Following the polymerization, a solvent exchange and hydrolysis of the anhydride ring are
25 performed.

The aqueous polymer solutions are adjusted in each case to pH 7.5 (using sodium hydroxide solution) and a solids content of 40.0% by weight.

30 Polymers 1, 4, 5, 8, 9, 10 and 11 are polymers (A) in accordance with the abovementioned definition.

Polymers 2, 3, 6, 7, 12, 13 and 14 are polymers (B) in accordance with the abovementioned definition.

- 5 Polymer 1: Copolymer of maleic acid and isobutene (weight ratio 70:30), Na salt, M_w 4000 g/mol, aqueous solution, pH 7.5, solids content: 40.0% by weight

Polymer 2: Copolymer of acrylic acid and 2-acrylamido-2-methylpropanesulfonic acid (weight ratio 75:25), Na salt, M_w 7000 g/mol, aqueous solution, pH 7.5, solids content:
10 40.0% by weight

Polymer 3: Copolymer of acrylic acid and 2-acrylamido-2-methylpropanesulfonic acid (weight ratio 75:25), Na salt, M_w 8000 g/mol, aqueous solution, pH 7.5, solids content:
15 40.0% by weight

Polymer 4: Copolymer of maleic acid and isoprenol (weight ratio 65:35), Na salt, M_w 4000 g/mol, aqueous solution, pH 7.5, solids content: 40.0% by weight

Polymer 5: Copolymer of maleic acid and isoprenol (weight ratio 60:40), Na salt, M_w 7500
20 g/mol, aqueous solution, pH 7.5, solids content: 40.0% by weight

Polymer 6: Polyacrylic acid, Na salt, M_w 1200 g/mol, aqueous solution, pH 7.5, solids content 40.0% by weight

25 Polymer 7: Polyacrylic acid, Na salt, M_w 3500 g/mol, aqueous solution, pH 7.5, solids content 40.0% by weight

Polymer 8: Copolymer of maleic acid, isoprenol and 2-acrylamido-2-methylpropane-sulfonic acid (weight ratio 40:40:20), Na salt, M_w 7000 g/mol, aqueous solution, pH 7.5,
30 solids content: 40.0% by weight

Polymer 9: Copolymer of maleic acid, isoprenol and acrylic acid (weight ratio 35:40:25), Na salt, M_w 3800 g/mol, aqueous solution, pH 7.5, solids content: 40.0% by weight

Polymer 10: Copolymer of maleic acid and methyl vinyl ether (weight ratio 70:30), Na salt, M_w 9500 g/mol, aqueous solution, pH 7.5, solids content 40.0% by weight

- 5 Polymer 11: Copolymer of maleic acid and vinyl acetate (weight ratio 60:40), Na salt, M_w 6500 g/mol, aqueous solution, pH 7.5, solids content 40.0% by weight

Polymer 12: Copolymer of acrylic acid and allylsulfonic acid (weight ratio 80:20), Na salt, M_w 5100, aqueous solution, solids content 40.0% by weight

10

Polymer 13: Copolymer of acrylic acid and isoprenol polyethylene glycol of the formula $\text{CH}_2=\text{C}(\text{CH}_3)\text{CH}_2\text{CH}_2-(\text{EO})_{11.3}-\text{H}$ (weight ratio 90:10), Na salt, M_w 6200 g/mol, aqueous solution, solids content 40.0% by weight

- 15 Polymer 14: Terpolymer of acrylic acid, 2-acrylamido-2-methylpropanesulfonic acid and allyl alcohol alkoxylate of the formula $\text{CH}_2=\text{CHCH}_2\text{O}-(\text{EO})_{16}-\text{H}$ (weight ratio 55:30:15), Na salt, M_w 8500 g/mol, aqueous solution, solids content 40.0% by weight

20 The polymer mixtures are produced by mixing the 40% strength by weight polymer solutions. The amounts of solution are chosen in such a manner that a mixture of the desired polymer composition results. A mixture having a 50:50 composition has identical quantitative fractions (in % by weight) of the polymers used.

Use as deposit inhibitor

Examples 1 to 3

5 Calcium carbonate inhibition test

A solution of NaHCO_3 , Mg_2SO_4 , CaCl_2 and polymer is shaken for 2 h at 70°C in the water bath. After filtering the still-warm solution through a 0.45 μm Millex filter, the Ca content of the filtrate is determined complexometrically or by means of a Ca^{2+} -selective electrode and
10 the CaCO_3 inhibition is determined by comparison of before/after in % in accordance with formula I hereinafter:

	Ca^{2+}	215 mg/l
	Mg^{2+}	43 mg/l
15	HCO_3^-	1220 mg/l
	Na^+	460 mg/l
	Cl^-	380 mg/l
	SO_4^{2-}	170 mg/l
	Polymer mixture (100% strength)	3 mg/l
20	Temperature	70°C
	Time	2 hours
	pH	8.0-8.5

Formula I:

CaCO₃ inhibition (%) =

mg (Ca²⁺) after 24 h – mg (Ca²⁺) blank value after 24 h/mg

(Ca²⁺) zero value – mg (Ca²⁺) blank value after 24 h

5

× 100

Table 1

	Mixture composition in % by weight	Inhibition [%]
Example 1		
Polymer 4		58.4
Polymer 7		80.7
Mixture 4/7	50:50	83.4
Mixture 4/7	35:65	86.8
Example 2		
Polymer 1		46.0
Polymer 3		64.8
Polymer 6		68.5
Mixture 1/3/6	30:30:40	72.0
Example 3		
Polymer 1		46.0
Polymer 13		66.7
Mixture 1/13	25:75	73.2

10 Examples 4 to 7

Calcium sulfate inhibition test

15 A solution of NaCl, Na₂SO₄, CaCl₂ and polymer was shaken for 24 h at 70°C in the water bath. After filtration of the still-warm solution through a 0.45 µm Millex filter, the Ca content

of the filtrate is determined complexometrically or by means of a Ca^{2+} -selective electrode and the CaSO_4 inhibition in % determined by before/after comparison in accordance with formula II hereinafter:

5	Ca^{2+}	2940 mg/l
	SO_4^{2-}	7200 mg/l
	Na^+	6400 mg/l
	Cl^-	9700 mg/l
	Polymer mixture (100% strength)	10 mg/l
10	Temperature	70°C
	Time	24 hours
	pH	8.0-8.5

Formula II:

15

$$\text{CaSO}_4 \text{ inhibition (\%)} = \frac{\text{mg (Ca}^{2+}\text{) after 24 h} - \text{mg (Ca}^{2+}\text{) blank value after 24 h}}{\text{(Ca}^{2+}\text{) zero value} - \text{mg (Ca}^{2+}\text{) blank value after 24 h}} \times 100$$

20 Table 2

	Mixture composition in % by weight	Inhibition [%]
Example 4		
Polymer 5		51.9
Polymer 6		91.0
Mixture 5/6	50:50	93.7
Example 5		
Polymer 7		68.9
Polymer 11		47.7
Mixture 7/11	70:30	72.3
Example 6		

Polymer 4		58.4
Polymer 12		78.9
Mixture 4/12	25:75	81.3
Example 7		
Polymer 4		58.4
Polymer 14		57.8
Mixture 4/14	50:50	66.0

Examples 8 to 10

Experiments on inhibiting basic Mg salt sediments (DSL method)

5

The deposit-inhibiting activity of the polymers according to the invention is carried out using a modified version of the "Differential Scale Loop (DSL)" instrument from PSL Systemtechnik. This is a "tube blocking system" as a fully automated laboratory system for studying precipitates and deposits of salts in pipelines and water pipes. In this instrument, in a modified mode of operation, a magnesium chloride solution A is mixed together with a sodium hydrogencarbonate solution B which comprises the polymer under test at a temperature of 120°C and a specific pressure of 2 bar at a mixing point in the volumetric ratio 1:1 and pumped at a constant flow rate through a test capillary of stainless steel at constant temperature. In this case, the differential pressure between mixing point (starter capillary) and capillary end is determined. A rise of the differential pressure indicates deposit formation within the capillary due to basic magnesium salts (hydromagnesite, brucite). The time measured up to a pressure rise of a defined height (0.1 bar) is a measure of the deposit-inhibiting activity of the polymer used.

20 The specific experimental conditions are:

Solution A: 100 mM MgCl₂

Solution B: 200 mM NaHCO₃

Concentration of the polymer after mixing A and B: 10 mg/l

25 Capillary length: 2.5 m

Capillary diameter: 0.88 mm

Capillary material: stainless steel

Temperature: 120°C

Total flow rate: 5ml/min

5 System pressure: 2 bar

Pressure rise threshold: 0.1 bar

Table 3: Time taken to pressurize by 0.1 bar (mean value from four measurements)

	Mixture composition in % by weight	Inhibition [min]
Example 8		
Polymer 1		18.5
Polymer 3		23.9
Mixture 1/3	50:50	28.0
Example 9		
Polymer 2		23.5
Polymer 8		24.9
Mixture 2/8	40:60	30.3
Example 10		
Polymer 6		8.2
Polymer 9		20.0
Polymer 10		17.7
Mixture 6/9/10	20:50:30	22.5

CLAIMS:

1. A polymer mixture in solid or aqueous form, comprising, based on the polymer fraction,

5

- (A) 5 to 95% by weight of a water-soluble or water-dispersible polymer having a weight-average molecular weight of 1000 to 20 000 g/mol determined by means of gel-permeation chromatography in comparison with polyacrylic acid standards, of

10

- (a1) 20 to 80% by weight of at least one monomer selected from the group consisting of C₂ to C₈ olefins, allyl alcohol, isoprenol, C₁ to C₄ alkyl vinyl ethers and vinyl esters of C₁ to C₄ monocarboxylic acids,

15

- (a2) 20 to 80% by weight of at least one monoethylenically unsaturated C₃ to C₈ carboxylic acid, an anhydride or salt of same,

- (a3) 0 to 50% by weight of one or more monomers comprising sulfonic acid groups,

20

- (B) 5 to 95% by weight of a water-soluble or water-dispersible polymer having a weight-average molecular weight of 1000 to 50 000 g/mol determined by means of gel-permeation chromatography in comparison with polyacrylic acid standards, of

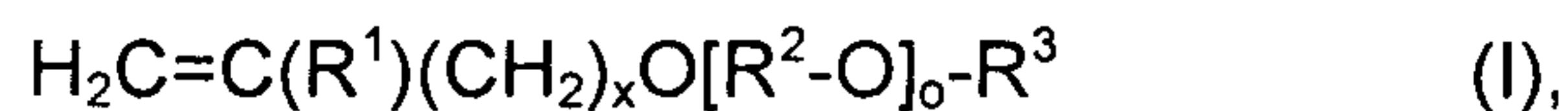
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- (b1) 30 to 100% by weight of at least one monoethylenically unsaturated C₃ to C₈ carboxylic acid, an anhydride or salt of same,

30

- (b2) 0 to 70% by weight of one or more monomers comprising sulfonic acid groups,

- (b3) 0 to 70% by weight of one or more nonionic monomers of the formula (I)



5 where R^1 is hydrogen or methyl, R^2 is identical or different, linear or branched, $\text{C}_2\text{-C}_6$ alkylene radicals, which can be arranged in blocks or randomly, and R^3 is hydrogen or a straight-chain or branched $\text{C}_1\text{-C}_4$ alkyl radical, x is 0, 1 or 2, and o is a number from 3 to 50.

2. The polymer mixture according to claim 1, characterized in that monomers (a1) are selected from the group consisting of isobutene, diisobutene, vinyl acetate, vinyl methyl ether, allyl alcohol and isoprenol.
10
3. The polymer mixture according to claim 1 or 2, wherein monomer (a2) or (b1) is selected from the group consisting of acrylic acid, methacrylic acid, ethacrylic acid, vinyl acetic acid, allyl acetic acid, crotonic acid, maleic acid, fumaric acid, mesaconic acid and itaconic acid, anhydrides thereof and water-soluble salts thereof.
15
4. The polymer mixture according to any one of claims 1 to 3, wherein monomer (a3) or (b2) is selected from the group consisting of 1-acrylamidopropanesulfonic acid, 2-acrylamido-2-propanesulfonic acid, 2-acrylamido-2-methylpropanesulfonic acid (AMPS), 2-methacrylamido-2-methylpropanesulfonic acid, 3-methacrylamido-2-hydroxypropanesulfonic acid, 2-hydroxy-3-(2-propenyloxy)propanesulfonic acid, 2-sulfoethyl methacrylate, styrenesulfonic acid, vinylsulfonic acid, allylsulfonic acid (ALS) and methallylsulfonic acid and the water-soluble salts thereof.
20
25
5. The polymer mixture according to any one of claims 1 to 4, wherein the polymer (A) is a copolymer of 20 to 60% by weight of monomer (a1) and 40 to 80% by weight of monomer (a2).
- 30 6. The polymer mixture according to any one of claims 1 to 5, wherein the polymer (A) is a copolymer of isobutene and maleic acid.

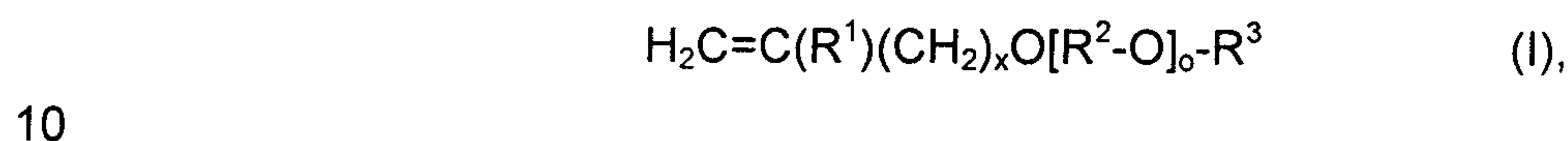
7. The polymer mixture according to any one of claims 1 to 5, wherein the polymer (A) is a copolymer of isoprenol and maleic acid.
- 5 8. The polymer mixture according to any one of claims 1 to 4, wherein the polymer (A) is a terpolymer of 25 to 50% by weight of monomer (a1), 30 to 60% by weight of monomer (a2) and 10 to 30% by weight of monomer (a3).
- 10 9. The polymer mixture according to any one of claims 1 to 4 and 8, wherein the polymer (A) is a terpolymer of isoprenol, maleic acid and 2-acrylamido-2-methyl-propanesulfonic acid or a terpolymer of isoprenol, maleic acid and allylsulfonic acid.
- 15 10. The polymer mixture according to any one of claims 1 to 4 and 8, wherein the polymer (A) is a terpolymer of isoprenol, maleic acid and acrylic acid.
11. The polymer mixture according to any one of claims 1 to 10, wherein polymer (B) is a homopolymer of a monoethylenically unsaturated C₃ to C₈ carboxylic acid, an anhydride or salt of same.
- 20 12. The polymer mixture according to claim 11, wherein polymer (B) is an acrylic acid homopolymer.
- 25 13. The polymer mixture according to any one of claims 1 to 10, wherein polymer (B) is a copolymer of 50 to 90% by weight of monomer (b1) and 10 to 50% by weight of monomer (b2).
- 30 14. The polymer mixture according to any one of claims 1 to 10, wherein polymer (B) is a copolymer of 50 to 95% by weight of monomer (b1) and 5 to 50% by weight of monomer (b3).
15. The polymer mixture according to any one of claims 1 to 10, wherein polymer (B) is a copolymer of 30 to 80% by weight of monomer (b1), 10 to 50% by weight of monomer (b2) and 5 to 50% by weight of monomer (b3).

16. The polymer mixture according to either claim 14 or 15, wherein monomer (b3) is that based on allyl alcohol ($R^1 = H$; $x = 1$) or isoprenol ($R^1 = \text{methyl}$; $x = 2$).
- 5 17. The polymer mixture according to any one of claims 1 to 10 and 13, wherein polymer (B) is a copolymer of acrylic acid and 2-acrylamido-2-methyl-propanesulfonic acid.
- 10 18. The polymer mixture according to any one of claims 1 to 10 and 13, wherein polymer (B) is a copolymer of acrylic acid and allylsulfonic acid.
19. A composition comprising
- 15 (A) 3 to 95% by weight of a water-soluble or water-dispersible polymer having a weight-average molecular weight of 1000 to 20 000 g/mol determined by means of gel-permeation chromatography in comparison with polyacrylic acid standards, of
- 20 (a1) 20 to 80% by weight of at least one monomer selected from the group consisting of C_2 to C_8 olefins, allyl alcohol, isoprenol, C_1 to C_4 alkyl vinyl ethers and vinyl esters of C_1 to C_4 monocarboxylic acids,
- (a2) 20 to 80% by weight of at least one monoethylenically unsaturated C_3 to C_8 carboxylic acid, an anhydride or salt of same,
- 25 (a3) 0 to 50% by weight of one or more monomers comprising sulfonic acid groups,
- 30 (B) 3 to 95% by weight of a water-soluble or water-dispersible polymer having a weight-average molecular weight of 1000 to 50 000 g/mol determined by means of gel-permeation chromatography in comparison with polyacrylic acid standards, of

(b1) 30 to 100% by weight of at least one monoethylenically unsaturated C₃ to C₈ carboxylic acid, an anhydride or salt of same,

5 (b2) 0 to 70% by weight of one or more monomers comprising sulfonic acid groups,

(b3) 0 to 70% by weight of one or more nonionic monomers of the formula (I)



where R¹ is hydrogen or methyl, R² is identical or different, linear or branched, C₂-C₆ alkylene radicals, which can be arranged in blocks or randomly, and R³ is hydrogen or a straight-chain or branched C₁-C₄ alkyl radical, x is 0, 1 or 2, and o is a number from 3 to 50,

15 (C) 0 to 80% by weight of phosphonates,

(D) 0 to 90% by weight of water;

20 (E) 0 to 50% by weight of additives such as polyphosphates, zinc salts, molybdate salts, organic corrosion inhibitors, biocides, complexing agents, surfactants or antifoams.

25 20. The use of polymer mixtures according to any one of claims 1 to 18 or of compositions according to claim 19 as deposit inhibitors in water-bearing systems.

21. The use according to claim 20 for inhibiting the precipitation and sedimentation of calcium salts and magnesium salts.

30 22. The use according to claim 21 for inhibiting the precipitation and sedimentation of calcium carbonate, calcium sulfate and basic magnesium salts.

23. The use according to any one of claims 20 to 22 in seawater desalination plants, brackish water desalination plants, cooling water systems and boiler feed water systems.