DESCRIPTION

TITLE OF INVENTION

Ophthalmic Solution Comprising Diquafosol

TECHNICAL FIELD

The present invention relates to an aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v) and a chelating agent at a concentration of 0.0001 to 1% (w/v), and relates to a method for producing this ophthalmic solution. The present invention also relates to a method for inhibiting formation of insoluble precipitates in an aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v) (hereinafter also referred to simply as "Diquafosol ophthalmic solution"), by adding a chelating agent at a concentration of 0.0001 to 1% (w/v) to the aqueous ophthalmic solution, a method for reducing eye irritation caused by the aqueous ophthalmic solution, and a method for enhancing preservative effectiveness of the aqueous ophthalmic solution.

BACKGROUND ART

Diquafosol is a purinergic receptor agonist also called P^1,P^4-di(uridine-5')tetraphosphate or Up_4U, and is known to have an effect of stimulating secretion of tears as disclosed in Japanese Patent No. 3652707 (PTD 1). Cornea, 23(8), 784-792 (2004) (NPD 1) describes that instillation of an ophthalmic solution comprising diquafosol tetrasodium salt has improved corneal epithelium disorder of dry eye patients. In our country, an ophthalmic solution comprising diquafosol tetrasodium salt at a concentration of 3% (w/v) is actually used as a remedy for dry eyes (product name: DIQUAS (registered trademark) ophthalmic solution 3%).

As for an ophthalmic solution, it is necessary for the solution to have physicochemical properties that are stable during the courses of production and distribution as well as the course of storage by a patient. In particular, regarding such an ophthalmic solution as the one in which precipitates are formed during the course of distribution or during storage by a patient, the precipitates cannot be removed afterward,

and therefore such an ophthalmic solution is undesirable for use as an ophthalmic solution. Although precipitates formed in an ophthalmic solution during the course of its production can be removed in the process of filtration sterilization of the ophthalmic solution, a filter is clogged during the filtration to accordingly deteriorate the efficiency of filtration sterilization, resulting in a problem of an increase of the production cost.

As to a method for inhibiting formation of precipitates in an ophthalmic solution, Japanese Patent Laying-Open No. 2007-182438 (PTD 2) discloses a method according to which glycerin is added to the ophthalmic solution, for example. As described in this document, the properties and/or the state of precipitates vary depending on the type of active ingredient and/or the type of additive, and accordingly the method for inhibiting formation of precipitates varies depending on the ophthalmic solution.

CITATION LIST

PATENT DOCUMENT

PTD 1: Japanese Patent No. 3652707

PTD 2: Japanese Patent Laying-Open No. 2007-182438

NON PATENT DOCUMENT

NPD 1: Cornea, 23(8), 784-792 (2004)

SUMMARY OF INVENTION

TECHNICAL PROBLEM

Thus, it is a challenge of interest to seek Diquafosol ophthalmic solution having stable physicochemical properties and a method for producing the same.

SOLUTION TO PROBLEM

The inventors of the present invention have carried out thorough studies to consequently find that insoluble precipitates are formed over time in Diquafosol ophthalmic solution during storage of the solution, and that addition of a chelating agent at a concentration of 0.0001 to 1% (w/v) can inhibit formation of the insoluble precipitates, and thereby reach the present invention. The inventors of the present invention have also found that addition of a chelating agent at a concentration of 0.0001

to 1% (w/v) to Diquafosol ophthalmic solution can reduce eye irritation caused by the ophthalmic solution and enhance the preservative effectiveness of the solution.

Specifically, the present invention provides an aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v) and a chelating agent at a concentration of 0.0001 to 1% (w/v) (hereinafter referred to simply as "the present ophthalmic solution").

The chelating agent in the present ophthalmic solution is preferably at least one type selected from the group consisting of edetic acid, citric acid, metaphosphoric acid, pyrophosphoric acid, polyphosphoric acid, malic acid, tartaric acid, phytic acid, and salts thereof; more preferably at least one type selected from the group consisting of edetic acid, citric acid, metaphosphoric acid, polyphosphoric acid, and salts thereof; and particularly preferably a salt of edetic acid.

In the present ophthalmic solution, the chelating agent is preferably at a concentration of 0.0005 to 0.5% (w/v), and particularly preferably at 0.001 to 0.1% (w/v) in the ophthalmic solution.

In the present ophthalmic solution, diquafosol or a salt thereof is at a concentration of preferably 1 to 10% (w/v), and particularly preferably 3% (w/v) in the ophthalmic solution.

Regarding the present ophthalmic solution, it is preferable that the chelating agent is a salt of edetic acid, the chelating agent is at a concentration of 0.001 to 0.1% (w/v) in the ophthalmic solution, and diquafosol or a salt thereof is at a concentration of 3% (w/v) in the ophthalmic solution.

Preferably, the present ophthalmic solution further comprises a preservative.

The present invention also provides a method for producing an aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v), comprising the step of mixing diquafosol or a salt thereof and a chelating agent in an amount that causes a final concentration of the chelating agent in the aqueous ophthalmic solution to be 0.0001 to 1% (w/v), to obtain an aqueous solution in which formation of insoluble precipitates is inhibited (hereinafter referred to simply as

"the present method for production").

Preferably, the present method for production further comprises the step of filtering the obtained aqueous solution through a filtration sterilization filter having a pore size of 0.1 to 0.5 μm.

The present invention further provides a method for inhibiting formation of insoluble precipitates in an aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v), by adding a chelating agent at a concentration of 0.0001 to 1% (w/v) to the aqueous ophthalmic solution.

The present invention further provides a method for reducing eye irritation caused by an aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v), by adding a chelating agent at a concentration of 0.0001 to 1% (w/v) to the aqueous ophthalmic solution.

The present invention further provides a method for enhancing preservative effectiveness of an aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v), by adding a chelating agent at a concentration of 0.0001 to 1% (w/v) to the aqueous ophthalmic solution.

ADVANTAGEOUS EFFECTS OF INVENTION

As is clear from the results of a storage stability test and a filtration performance test described later herein, according to the present ophthalmic solution, Diquafosol ophthalmic solution not comprising a chelating agent has been found to inhibit formation of insoluble precipitates during storage which are found in Diquafosol ophthalmic solution, as well as deterioration of filtration performance in the course of production (course of filtration sterilization). Further, as proved by the results of an eye irritation evaluation test and a preservative effectiveness test described later herein, the present ophthalmic solution has been confirmed as reducing eye irritation and having enhanced preservative effectiveness in comparison to Diquafosol ophthalmic solution comprising no chelating agent. Accordingly, the present ophthalmic solution has physicochemical properties that are stable during the courses of production and distribution as well as the course of storage by a patient. In addition, the present

ophthalmic solution allows reduction of eye irritation and has excellent preservative effectiveness. In particular, since degradation of the filtration performance in the course of production (course of filtration sterilization) is inhibited, the present ophthalmic solution can be subjected to efficient filtration sterilization in the course of production, thereby contributing to a decrease in production cost.

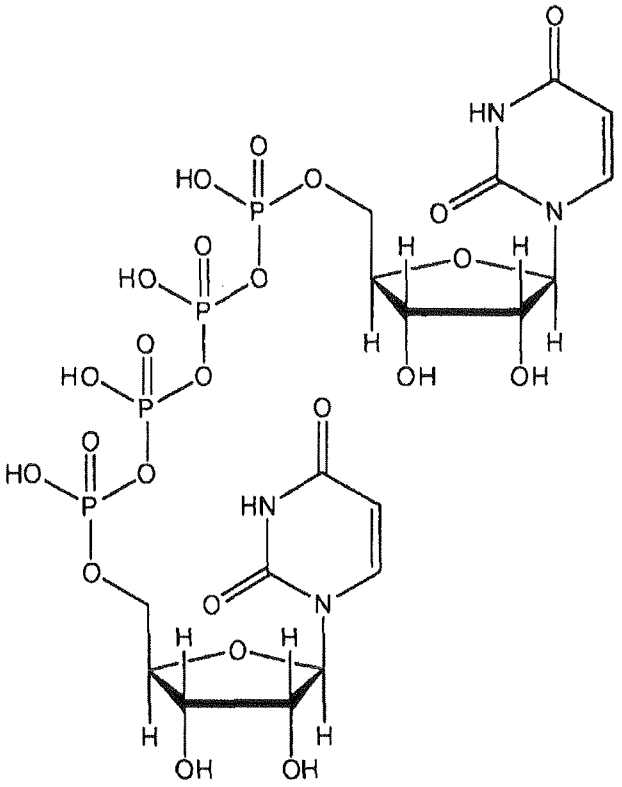
BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a graph showing the results of a filtration performance test conducted for each Diquafosol ophthalmic solution of a formulation containing edetate and a formulation containing no chelating agent, where the vertical axis represents the amount of filtration (g) and the horizontal axis represents the time (minutes).

Fig. 2 is a graph showing the results of a filtration performance test conducted for each Diquafosol ophthalmic solution of a formulation containing no chelating agent, or a formulation containing edetate, citric acid, metaphosphate, or polyphosphate, where the vertical axis represents the amount of filtration per effective filtration area (g/cm^2) and the horizontal axis represents the time (minutes).

DESCRIPTION OF EMBODIMENTS

Diquafosol is a compound represented by the following structural formula.



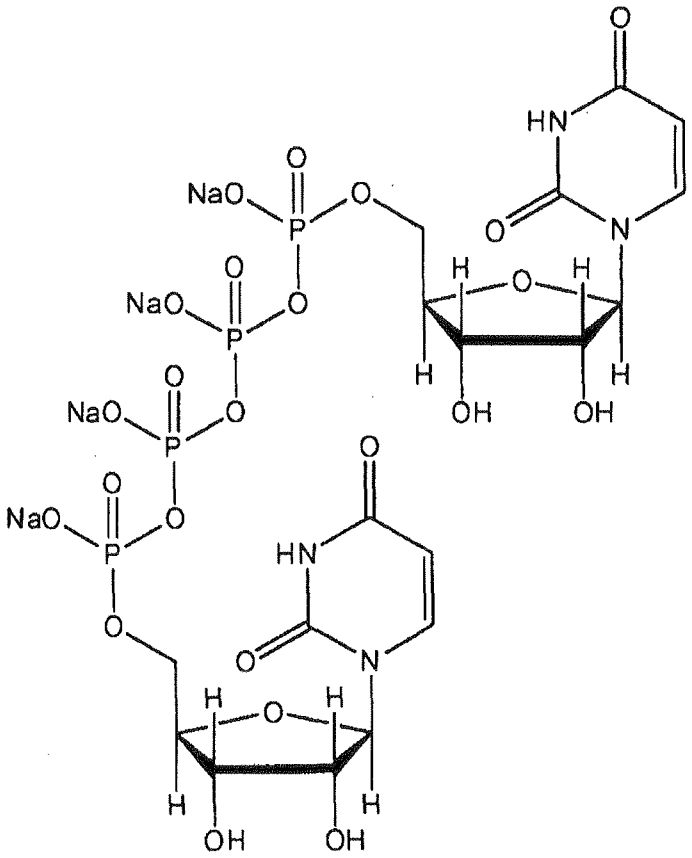
"A salt of diquafosol" is not particularly limited as long as it is a pharmaceutically acceptable salt, and may for example be: a metal salt with lithium, sodium, potassium, calcium, magnesium, zinc, or the like; a salt with an inorganic acid such as hydrochloric acid, hydrobromic acid, hydriodic acid, nitric acid, sulfuric acid, or phosphoric acid; a salt with an organic acid such as acetic acid, fumaric acid, maleic acid, succinic acid, citric acid, tartaric acid, adipic acid, gluconic acid, glucoheptonic acid, glucuronic acid, terephthalic acid, methanesulfonic acid, lactic acid, hippuric acid, 1,2-ethanedisulfonic acid, isethionic acid, lactobionic acid, oleic acid, pamoic acid, polygalacturonic acid, stearic acid, tannic acid, trifluoromethane sulfonic acid, benzenesulfonic acid, p-toluene sulfonic acid, lauryl sulfate ester, methyl sulfate, naphthalene sulfonic acid, or sulfosalicylic acid; a quaternary ammonium salt with methyl bromide, methyl iodide, or the like; a salt with halogen ion such as bromine ion, chlorine ion, or iodine ion; a salt with ammonia; or a salt with organic amine such as triethylenediamine, 2-aminoethanol, 2,2-iminobis(ethanol), 1-deoxy-1-(methylamino)-

2-D-sorbitol, 2-amino-2-(hydroxymethyl)-1,3-propanediol, procaine, or N,N-bis(phenylmethyl)-1,2-ethanediamine.

Regarding the present invention, "diquafosol or a salt thereof" also includes a hydrate and an organic solvate of diquafosol (free form) or a salt thereof.

In the case where diquafosol or a salt thereof has a crystal polymorph and a group of crystal polymorphs (crystal polymorph system), these crystal polymorph and group of crystal polymorphs (crystal polymorph system) are also included in the scope of the present invention. A group of crystal polymorphs (crystal polymorph system) herein means individual crystal forms in respective stages where the crystal form changes depending on conditions and states in manufacture, crystallization, storage and the like of the crystals, as well as the entire course of change.

"Diquafosol or a salt thereof" of the present invention is preferably a sodium salt of diquafosol, and particularly preferably diquafosol tetrasodium salt (hereinafter also referred to simply as "diquafosol sodium") represented by the following structural formula.



Diquafosol or a salt thereof can be produced in accordance with a method for example disclosed in Japanese National Patent Publication No. 2001-510484.

While the present ophthalmic solution may also comprise an active ingredient other than diquafosol or a salt thereof, the present ophthalmic solution preferably comprises diquafosol or a salt thereof as a sole active ingredient.

The concentration of diquafosol or a salt thereof in the present ophthalmic solution is 0.1 to 10% (w/v), which is preferably 1 to 10% (w/v) and particularly preferably 3% (w/v).

The present method for production uses diquafosol or a salt thereof in such an amount that causes the final concentration of diquafosol or a salt thereof in an aqueous ophthalmic solution obtained through this production method to be 0.1 to 10% (w/v), which is preferably an amount that causes the final concentration thereof to be 1 to 10% (w/v), and particularly preferably an amount that causes the final concentration thereof

to be 3% (w/v).

Regarding the present invention, "aqueous ophthalmic solution" means an ophthalmic solution in which water is used as a solvent.

Regarding the present invention, "chelating agent" is not particularly limited as long as it is a compound that chelates metallic ions, and may for example be: edetic acid or a salt thereof such as edetic acid (ethylene diamine tetraacetic acid), monosodium edetate, disodium edetate, trisodium edetate, tetrasodium edetate, dipotassium edetate, tripotassium edetate, or tetrapotassium edetate; citric acid or a salt thereof such as citric acid, monosodium citrate, disodium citrate, trisodium citrate, monopotassium citrate, dipotassium citrate, or tripotassium citrate; metaphosphoric acid or a salt thereof such as metaphosphoric acid, sodium metaphosphate, or potassium metaphosphate; pyrophosphoric acid or a salt thereof such as pyrophosphoric acid, tetrasodium pyrophosphate, or tetrapotassium pyrophosphate; polyphosphoric acid or a salt thereof such as polyphosphoric acid, sodium polyphosphate, or potassium polyphosphate; malic acid or a salt thereof such as monosodium malate, disodium malate, monopotassium malate, or dipotassium malate; tartaric acid or a salt thereof such as sodium tartrate, potassium tartrate, or sodium potassium tartrate; or phytic acid or a salt thereof such as sodium phytate or potassium phytate. Regarding the present invention, "edetic acid, citric acid, metaphosphoric acid, pyrophosphoric acid, polyphosphoric acid, malic acid, tartaric acid, phytic acid, and salts thereof" also include hydrates and organic solvates of respective free forms or salts thereof.

Regarding the present invention, preferred chelating agents are edetic acid, a salt of edetic acid (edetate), citric acid, a salt of citric acid (citrate), metaphosphoric acid, a salt of metaphosphoric acid (metaphosphate), polyphosphoric acid, and a salt of polyphosphoric acid (polyphosphate), and particularly preferred chelating agents are a sodium salt of edetic acid (including hydrates such as disodium edetate hydrate), citric acid (including hydrates such as citric acid monohydrate), a sodium salt of metaphosphoric acid (sodium metaphosphate), and a sodium salt of polyphosphoric

acid (sodium polyphosphate).

Regarding the present invention, a most preferred edetate is disodium edetate hydrate (hereinafter also referred to simply as "sodium edetate hydrate").

The concentration of the chelating agent in the present ophthalmic solution is 0.0001 to 1% (w/v), preferably 0.0005 to 0.5% (w/v), and particularly preferably 0.001 to 0.1% (w/v).

The amount of the chelating agent used by the present method for production is such an amount that causes the final concentration of the chelating agent in an aqueous ophthalmic solution obtained through this method to be 0.0001 to 1% (w/v), more preferably such an amount that causes the final concentration of the chelating agent to be 0.0005 to 0.5% (w/v), and particularly preferably such an amount that causes the final concentration of the chelating agent to be 0.001 to 0.1% (w/v).

The present ophthalmic solution may further comprise a preservative. "Preservative" of the present invention may for example be benzalkonium chloride, benzethonium chloride, chlorhexidine gluconate, paraben, sorbic acid, chlorobutanol, boric acid, or chlorite, and is particularly preferably benzalkonium chloride.

The most preferred benzalkonium chloride added to the present ophthalmic solution is a benzalkonium chloride represented by a general formula: $[C_6H_5CH_2N(CH_3)_2R]Cl$ where the carbon number of an alkyl group R is 12 (hereinafter also referred to simply as "BAK-C_{12}").

Regarding the present method for production, the aforementioned preservative may further be added when diquafosol or a salt thereof and a chelating agent are mixed together.

In the case where the present ophthalmic solution further comprises a preservative, the concentration of the preservative is not particularly limited as long as it exhibits predetermined preservative effectiveness. In the case where the preservative is benzalkonium chloride, the concentration thereof is preferably 0.0001 to 0.1% (w/v), more preferably 0.0005 to 0.01% (w/v), and particularly preferably 0.001 to 0.005% (w/v).

In the case where the present method for production further uses a preservative, the amount of the preservative to be used is not particularly limited as long as it exhibits predetermined preservative effectiveness. In the case where the preservative is benzalkonium chloride, the amount of the preservative is preferably such an amount that causes the final concentration of the preservative in an aqueous ophthalmic solution obtained through this method to be 0.0001 to 0.1% (w/v), more preferably such an amount that causes the final concentration thereof to be 0.0005 to 0.01% (w/v), and particularly preferably such an amount that causes the final concentration thereof to be 0.001 to 0.005% (w/v).

To the present ophthalmic solution, a generally-used art may be applied to add a pharmaceutically acceptable additive as required. For example, any of: buffer agents such as sodium phosphate, sodium hydrogen phosphate, sodium dihydrogen phosphate, sodium acetate, and epsilon aminocaproic acid; isotonizing agents such as sodium chloride, potassium chloride, and concentrated glycerin; surfactants such as polyoxyethylene sorbitan monooleate, poloxyl 40 stearate, and polyoxyethylene hydrogenated castor oil, and the like may be selected as required and added to the present ophthalmic solution. The pH of the present ophthalmic solution may at least fall in an ophthalmologically acceptable range, and usually it preferably falls in a range of 4 to 8.

Regarding the present method for production, the aforementioned additive may further be added when diquafosol and a chelating agent are mixed together.

The present ophthalmic solution may be subjected to a filtration sterilization process or any of other sterilization processes, and the present ophthalmic solutions thus sterilized are also included in the scope of the present invention.

Regarding the present method for production, an aqueous solution obtained by mixing diquafosol or a salt thereof and a chelating agent together may further be sterilized. While the method for sterilization is not particularly limited as long as the method can sterilize the obtained aqueous solution, the method is preferably filtration sterilization.

Regarding the present invention, "filtration sterilization" is not particularly limited as long as it can sterilize the aqueous solution through filtering. Preferably, the solution is filtered through a filtration sterilization filter having a pore size of 0.1 to 0.5 μm.

Regarding the present invention, "insoluble precipitate" means a foreign body that has been formed in the course of production, distribution, and/or storage of the present ophthalmic solution and will not be dissolved again. "Formation of insoluble precipitate" regarding the present invention means both or one of: (a) a visible foreign body is formed in the ophthalmic solution; and (b) while no visible foreign body is formed in the ophthalmic solution, degradation of the filtration performance occurs during filtration sterilization.

Regarding the present invention, "formation of insoluble precipitates is inhibited" means that the ophthalmic solution comprising diquafosol or a salt thereof at a prescribed concentration shows both or one of: (a) reduction of the frequency of formation and/or the amount of visible foreign bodies in the ophthalmic solution that are found immediately after production or during storage of the ophthalmic solution (including the case where visible foreign bodies are not found at all); and (b) inhibition of deterioration of the filtration performance during filtration sterilization (including the case where deterioration of the filtration performance does not occur at all), in comparison to the ophthalmic solution comprising diquafosol or a salt thereof at the same concentration but comprising no chelating agent.

The present invention further provides a method for inhibiting formation of insoluble precipitates in an aqueous ophthalmic solution comprising diquafosol or a salt thereof, by adding a chelating agent at a concentration of 0.0001 to 1% (w/v) to the aqueous ophthalmic solution. Regarding the present invention, "inhibiting formation of insoluble precipitates" is used synonymously with "formation of insoluble precipitates is inhibited". The definition of each term regarding the method for inhibiting formation of insoluble precipitates is the same as described above, and preferred embodiments are similar to those as described above as well.

The present invention further provides a method for reducing eye irritation caused by an aqueous ophthalmic solution comprising diquafosol or a salt thereof, by adding a chelating agent at a concentration of 0.0001 to 1% (w/v) to the aqueous ophthalmic solution. Regarding the present invention, "reducing eye irritation" means that the occurrence frequency (occurrence rate) of eye irritation as a side effect caused when an ophthalmic solution comprising diquafosol or a salt thereof at a prescribed concentration is applied to a dry-eye patient is lower than that in the case of the ophthalmic solution comprising diquafosol or a salt thereof at the same concentration but not comprising a chelating agent. Furthermore, the definitions of other terms regarding the method for reducing eye irritation are the same as described above, and preferred embodiments are similar to those as described above as well.

The present invention further provides a method for enhancing preservative effectiveness of an aqueous ophthalmic solution comprising diquafosol or a salt thereof, by adding a chelating agent at a concentration of 0.0001 to 1% (w/v) to the aqueous ophthalmic solution. Regarding the present invention, "enhancing preservative effectiveness" means that the ophthalmic solution comprising diquafosol or a salt thereof at a prescribed concentration is less in the amount of a preservative that needs to be added for passing a preservative effectiveness test than the ophthalmic solution comprising diquafosol or a salt thereof at the same concentration but not comprising a chelating agent. Furthermore, the definitions of other terms regarding the method for enhancing preservative effectiveness are the same as described above, and preferred embodiments are similar to those as described above as well.

In the following, the results of a storage stability test, a filtration performance test, an eye irritation evaluation test, and a preservative effectiveness test, as well as drug formulation examples will be illustrated. These examples are presented for the sake of better understanding of the present invention and are not to limit the scope of the present invention.

Examples

[Storage Stability Test]

It was visually confirmed whether or not appearance of Diquafosol ophthalmic solution had been changed during its storage, and the influence of edetate, which was a chelating agent, on the change of the appearance was examined.

Sample Preparation

- Formulation containing no chelating agent

3 g of diquafosol sodium, 0.2 g of sodium hydrogen phosphate, 0.41 g of sodium chloride, 0.15 g of potassium chloride, and 0.0075 g of benzalkonium chloride were dissolved in water so that the resultant solution was 100 mL, to which a pH adjuster was added to adjust the pH to 7.5 and the osmotic pressure ratio to 1.0.

- Formulation containing 0.001 or 0.1% (w/v) edetate

3 g of diquafosol sodium, 0.2 g of sodium hydrogen phosphate, 0.41 g of sodium chloride, 0.15 g of potassium chloride, 0.001 g or 0.1 g of sodium edetate hydrate, and 0.002 g of benzalkonium chloride were dissolved in water so that the resultant solution was 100 mL, to which a pH adjuster was added to adjust the pH to 7.5 and the osmotic pressure ratio to 1.0.

Test Method

The above-described formulation containing no chelating agent and formulation containing 0.001 or 0.1% (w/v) edetate were each stored in a glass container at 25°C for three months, and thereafter it was visually confirmed whether or not their appearance had been changed.

Test Results

The test results are indicated in Table 1.

[Table 1]

formulation	change of appearance
formulation containing no chelating agent	formation of insoluble precipitates (white particulates)
formulation containing 0.001% (w/v) edetate	no change
formulation containing 0.1% (w/v) edetate	no change

As is clear from Table 1, it was confirmed that visible insoluble precipitates were formed in the formulation containing no chelating agent during storage. In

contrast, the formulations containing edetate demonstrated that formation of these insoluble precipitates was inhibited.

Discussion

It was suggested that, in Diquafosol ophthalmic solution comprising a chelating agent, insoluble precipitates were not formed in the course of distribution and the course of storage by a patient, or the frequency of formation and the amount of insoluble precipitates in these courses were reduced.

[Filtration Performance Test]

It was confirmed how the filtration performance had changed over time during filtration sterilization of Diquafosol ophthalmic solution, and the influence of edetate, which was a chelating agent, on this change was examined.

Sample Preparation

- Formulation containing no chelating agent

30 g of diquafosol sodium, 2 g of sodium hydrogen phosphate, 4.1 g of sodium chloride, 1.5 g of potassium chloride, and 0.075 g of benzalkonium chloride were dissolved in water so that the resultant solution was 1000 mL, to which a pH adjuster was added to adjust the pH to 7.5 and the osmotic pressure ratio to 1.0.

- Formulation containing 0.001% (w/v) edetate

30 g of diquafosol sodium, 2 g of sodium hydrogen phosphate, 4.1 g of sodium chloride, 1.5 g of potassium chloride, 0.01 g of sodium edetate hydrate, and 0.075 g of benzalkonium chloride were dissolved in water so that the resultant solution was 1000 mL, to which a pH adjuster was added to adjust the pH to 7.5 and the osmotic pressure ratio to 1.0.

Test Method

Each preparation was filtered using, as filtration filters, two-stage hydrophilic PVDF membrane filters (manufactured by Nihon Pall Ltd., Fluorodyne II disc filter ϕ47 mm, pore size 0.2 μm (model FTKDFL)) at a filtration pressure of 200 kPa and room temperature. The time for filtration and the amount of filtration at this time were measured, and the relation therebetween was plotted.

Test Results

Fig. 1 is a graph showing the results of the filtration performance test conducted for each Diquafosol ophthalmic solution of the formulation containing edetate and the formulation containing no chelating agent, where the vertical axis represents the amount of filtration (g) and the horizontal axis represents the time for filtration (minutes). As is clear from Fig. 1, regarding the formulation containing no chelating agent, reduction of the amount of filtration (reduction of the rate of filtration) was found during filtration sterilization. In contrast, regarding the formulation containing edetate, it was demonstrated that reduction of the rate of filtration was completely inhibited.

Discussion

It was suggested that, as to Diquafosol ophthalmic solution comprising a chelating agent, reduction of the rate of filtration in the course of production (course of filtration sterilization) was completely inhibited, and thus the solution could be subjected to filtration sterilization more efficiently, in comparison to Diquafosol ophthalmic solution comprising no chelating agent. The cause of the reduction of the rate of filtration that has been found regarding Diquafosol ophthalmic solution comprising no chelating agent is considered as clogging with insoluble precipitates (including invisible ones).

[Filtration Performance Test - 2]

A comparison and an examination were made on respective influences of a chelating agent which was edetate and a chelating agent other than edetate, on how the filtration performance had changed over time during filtration sterilization of Diquafosol ophthalmic solution.

Sample Preparation

- Formulation containing no chelating agent

30 g of diquafosol sodium, 2 g of sodium hydrogen phosphate, 4.1 g of sodium chloride, 1.5 g of potassium chloride, and 0.075 g of benzalkonium chloride were dissolved in water so that the resultant solution was 1000 mL, to which a pH adjuster

was added to adjust the pH to 7.5 and the osmotic pressure ratio to 1.0.

- Formulation containing 0.01% (w/v) edetate

30 g of diquafosol sodium, 2 g of sodium hydrogen phosphate, 4.1 g of sodium chloride, 1.5 g of potassium chloride, 0.1 g of sodium edetate hydrate, and 0.075 g of benzalkonium chloride were dissolved in water so that the resultant solution was 1000 mL, to which a pH adjuster was added to adjust the pH to 7.5 and the osmotic pressure ratio to 1.0.

- Formulation containing 0.01% (w/v) citric acid

30 g of diquafosol sodium, 2 g of sodium hydrogen phosphate, 4.1 g of sodium chloride, 1.5 g of potassium chloride, 0.1 g of citric acid monohydrate, and 0.075 g of benzalkonium chloride were dissolved in water so that the resultant solution was 1000 mL, to which a pH adjuster was added to adjust the pH to 7.5 and the osmotic pressure ratio to 1.0.

- Formulation containing 0.01% (w/v) metaphosphate

30 g of diquafosol sodium, 2 g of sodium hydrogen phosphate, 4.1 g of sodium chloride, 1.5 g of potassium chloride, 0.1 g of sodium metaphosphate, and 0.075 g of benzalkonium chloride were dissolved in water so that the resultant solution was 1000 mL, to which a pH adjuster was added to adjust the pH to 7.5 and the osmotic pressure ratio to 1.0.

- Formulation containing 0.01% (w/v) polyphosphate

30 g of diquafosol sodium, 2 g of sodium hydrogen phosphate, 4.1 g of sodium chloride, 1.5 g of potassium chloride, 0.1 g of sodium polyphosphate, and 0.075 g of benzalkonium chloride were dissolved in water so that the resultant solution was 1000 mL, to which a pH adjuster was added to adjust the pH to 7.5 and the osmotic pressure ratio to 1.0.

Test Method

Each preparation was filtered using, as filtration filters, two-stage hydrophilic PVDF membrane filters (manufactured by Nihon Pall Ltd., Fluorodyne II disc filter ϕ25 mm, pore size 0.2 μm (model FTKDFL)) at a filtration pressure of 200 kPa and

room temperature. The time for filtration and the amount of filtration per effective filtration area at this time were measured, and the relation therebetween was plotted.

Test Results

Fig. 2 is a graph showing the results of the filtration performance test conducted for each Diquafosol ophthalmic solution of the formulation containing no chelating agent, or the formulation containing edetate, citric acid, metaphosphate, or polyphosphate, where the vertical axis represents the amount of filtration per effective filtration area (g/cm^2) and the horizontal axis represents the time for filtration (minutes). As is clear from Fig. 2, regarding the formulation containing no chelating agent, reduction of the amount of filtration (reduction of the rate of filtration) was found during filtration sterilization. In contrast, as to the formulation containing citric acid, metaphosphate, or polyphosphate, it was demonstrated that reduction of the rate of filtration was completely inhibited, like the formulation containing edetate.

Discussion

It was suggested that, regarding Diquafosol ophthalmic solution comprising a chelating agent, reduction of the rate of filtration in the course of production (course of filtration sterilization) was completely inhibited, and thus the solution could be subjected to filtration sterilization more efficiently relative to Diquafosol ophthalmic solution comprising no chelating agent.

[Eye Irritation Evaluation Test]

The package insert of "DIQUAS (registered trademark) ophthalmic solution 3%" that is Diquafosol ophthalmic solution comprising no chelating agent describes that eye irritation was observed as a side effect in 6.7% of dry-eye patients who have used this ophthalmic solution. Thus, using an n-heptanol-induced corneal epithelial abrasion model showing corneal epithelium disorder like those found in dry-eye patients, it was examined how addition of a chelating agent exerted an influence upon eye irritation by Diquafosol ophthalmic solution.

Sample Preparation

- Formulation containing 3% (w/v) diquafosol sodium/containing no chelating

agent

3 g of diquafosol sodium, 0.2 g of sodium hydrogen phosphate, 0.41 g of sodium chloride, 0.15 g of potassium chloride, and 0.0075 g of benzalkonium chloride were dissolved in water so that the resultant solution was 100 mL, to which a pH adjuster was added to adjust the pH to 7.2 to 7.8 and the osmotic pressure ratio to 1.0 to 1.1.

- Formulation containing 3% (w/v) diquafosol sodium/containing edetate

3 g of diquafosol sodium, 0.2 g of sodium hydrogen phosphate, 0.41 g of sodium chloride, 0.15 g of potassium chloride, 0.01 g of sodium edetate hydrate, and 0.002 g of benzalkonium chloride were dissolved in water so that the resultant solution was 100 mL, to which a pH adjuster was added to adjust the pH to 7.2 to 7.8 and the osmotic pressure ratio to 1.0 to 1.1.

- Formulation containing 8% (w/v) diquafosol sodium/containing no chelating agent

8 g of diquafosol sodium, 0.2 g of sodium hydrogen phosphate, and 0.0075 g of benzalkonium chloride were dissolved in water so that the resultant solution was 100 mL, to which a pH adjuster was added to adjust the pH to 7.2 to 7.8 and the osmotic pressure ratio to 1.0 to 1.1.

- Formulation containing 8% (w/v) diquafosol sodium/containing edetate

8 g of diquafosol sodium, 0.2 g of sodium hydrogen phosphate, 0.01 g of sodium edetate hydrate, and 0.002 g of benzalkonium chloride were dissolved in water so that the resultant solution was 100 mL, to which a pH adjuster was added to adjust the pH to 7.2 to 7.8 and the osmotic pressure ratio to 1.0 to 1.1.

- Vehicle

0.2 g of sodium hydrogen phosphate, 0.75 g of sodium chloride, 0.15 g of potassium chloride, and 0.0075 g of benzalkonium chloride were dissolved in water so that the resultant solution was 100 mL, to which a pH adjuster was added to adjust the pH to 7.2 to 7.8 and the osmotic pressure ratio to 1.0 to 1.1.

Test Method

After treatment with n-heptanol was given to a cornea of the rabbit's left eye (for 1 minute), the corneal epithelium was peeled. After 16 to 18 hours, a vehicle, a formulation containing 3% (w/v) diquafosol sodium/containing no chelating agent, or a formulation containing 3% (w/v) diquafosol sodium/containing edetate was applied once to the eye (50 μL/eye). Then, the number of eye-blinking times for 1 minute after the application was measured and the symptoms related to pain during the application were observed. The signs related to pains such as closed eyes and half-closed eyes for 5 minutes after the application were subsequently observed (four examples in one group).

About 1 hour after the above-described observation, a vehicle, a formulation containing 8% (w/v) diquafosol sodium/containing no chelating agent or a formulation containing 8% (w/v) diquafosol sodium/containing edetate was applied once (50 μm/eye) to the corresponding rabbit's left eye to which the vehicle, the formulation containing 3% (w/v) diquafosol sodium/containing no chelating agent, or the formulation containing 3% (w/v) diquafosol sodium/containing edetate was applied. Then, a similar observation was carried out.

Test Results

The test results are indicated in Tables 2 and 3.

[Table 2]

formulation		vehicle	formulation containing 3% (w/v) diquafosol sodium /containing no chelating agent	formulation containing 3% (w/v) diquafosol sodium /containing edetate
number of examples		4	4	4
number of eye-blinking times (1 min after application)	number of eye-blinking times (times/min) (mean ± SD)	1.0±1.2	2.5±2.4	1.8±1.5
	signs related to pain	-	2 examples of half-closed eyes (10 sec and 3 sec)	-
symptoms related to pain (after 1 to 5 min from application)	half-closed eyes/ closed eyes	1 example (15 sec)	4 examples (intermittent)	1 example (10 sec)

[Table 3]

formulation		vehicle	formulation containing 8% (w/v) diquafosol sodium /containing no chelating agent	formulation containing 8% (w/v) diquafosol sodium /containing edetate
number of examples		4	4	4
number of eye-blinking times (1 min after application)	number of eye-blinking times (times/min) (mean ± SD)	1.5±1.7	2.8±1.7	2.0±2.4
	signs related to pain	-	2 examples of half-closed eyes (10 sec × 5 times and 6 sec)	-
symptoms related to pain (after 1 to 5 min from application)	half-closed eyes/ closed eyes	1 example (5 sec)	3 examples (intermittent or continuous)	-

As is clear from Tables 2 and 3, regarding the formulation containing no chelating agent, half-closed eyes were observed in two of four examples in 1 minute after the application also in the case where 3% (w/v) or 8% (w/v) diquafosol sodium was applied. This tendency was further more remarkable after 1 to 5 minutes from the application. In contrast, regarding the formulation containing edetate, half-closed eyes/closed eyes were observed in one of four examples after 1 to 5 minutes from the application only in the case where 3% (w/v) diquafosol sodium was applied, but the occurrence frequency was approximately the same as that of the group to which a vehicle was applied.

Discussion

As described above, regarding Diquafosol ophthalmic solution, it was suggested that half-closed eyes/closed eyes representing signs related to pain were caused with high frequency in an n-heptanol-induced corneal epithelial abrasion model showing corneal epithelium disorder like those found in dry-eye patients, while addition of a chelating agent to this ophthalmic solution allowed a decrease in occurrence frequency of these events to the level achieved in the case where the vehicle was applied. In other words, it is considered that addition of a chelating agent allows reduction of eye irritation as a side effect observed with certain frequency when Diquafosol ophthalmic solution containing no chelating agent is applied to a dry-eye patient.

[Preservative Effectiveness Test]

A preservative effectiveness test was conducted in order to confirm the influence of a chelating agent on the preservative effectiveness of Diquafosol ophthalmic solution.

Sample Preparation

- Formulation containing no chelating agent

3 g of diquafosol sodium, 0.2 g of sodium hydrogen phosphate, 0.41 g of sodium chloride, 0.15 g of potassium chloride, and 0.0036 g of benzalkonium chloride were dissolved in water so that the resultant solution was 100 mL, to which a pH adjuster was added to adjust the pH to 7.2 to 7.8 and the osmotic pressure ratio to 1.0 to

1.1.

- Formulation containing 0.01% (w/v) edetate

3 g of diquafosol sodium, 0.2 g of sodium hydrogen phosphate, 0.41 g of sodium chloride, 0.15 g of potassium chloride, 0.01 g of sodium edetate hydrate, and 0.0024 g of benzalkonium chloride were dissolved in water so that the resultant solution was 100 mL, to which a pH adjuster was added to adjust the pH to 7.2 to 7.8 and the osmotic pressure ratio to 1.0 to 1.1.

Test Method

The preservative effectiveness test was conducted in accordance with the preservative effectiveness test method defined by the Japanese Pharmacopoeia, 15th edition. For this test, the following test microorganisms were used: Esherichia Coli (E. coli), Pseudomonas aeruginosa (P. aeruginosa), Staphylococcus aureus (S. aureus), Candida albicans (C. albicans), and Aspergillus braziliensis (A. braziliensis).

Test Results

The test results are indicated in Table 4.

[Table 4]

Ingredients			formulation containing no chelating agent	formulation containing edetate
diquafosol sodium			3%	3%
sodium hydrogen phosphate			0.2%	0.2%
sodium chloride			0.41%	0.41%
potassium chloride			0.15%	0.15%
sodium edetate hydrate			-	0.01%
benzalkonium chloride			0.0036%	0.0024%
test results (log reduction)	E. coli	2 wks	N.D.	N.D.
		4 wks	N.D.	N.D.
	P. aeruginosa	2 wks	N.D.	N.D.
		4 wks	4.2	N.D.
	S. aureus	2 wks	N.D.	N.D.
		4 wks	N.D.	N.D.
	C. albicans	2 wks	5.6	>4.3
		4 wks	N.D.	N.D.
	A. braziliensis	2 wks	3.0	2.9
		4 wks	5.1	>4.4
Conclusions			Not passed*	Passed

N.D.: not detected
*The formulation containing no chelating agent did not pass the criterion because growth of P. aeruginosa was found in the 4th week.

The test results in Table 4 indicate to what extent the number of viable microorganisms has decreased in the test relative to the number of inoculated microorganisms, based on log reduction. For example, the log reduction "1" indicates that the number of viable microorganisms in the test has decreased to 10% relative to the number of inoculated microorganisms.

As indicated in Table 4, the formulation containing no chelating agent did not pass the criterion (Category IA) of the preservative effectiveness test of the Japanese Pharmacopoeia even though the concentration of blended benzalkonium chloride serving as a preservative was 0.0036% (w/v). In contrast, the formulation containing edetate passed the above-referenced criterion even though the concentration of blended benzalkonium chloride was 0.0024% (w/v). Accordingly, the formulation containing

edetate exhibited remarkably enhanced preservative effectiveness, in comparison to the formulation containing no chelating agent.

Discussion

The above-described results suggest that addition of a chelating agent to Diquafosol ophthalmic solution significantly enhances the preservative effectiveness of the solution. In other words, it is considered that the present ophthalmic solution allows reduction of the concentration of the preservative in the ophthalmic solution in comparison to Diquafosol ophthalmic solution containing no chelating agent.

[Preparation Examples]

Preparation examples will now be given to describe the drug of the present invention more specifically. The present invention, however, is not limited solely to these preparation examples.

Formulation Example 1: ophthalmic solution (3% (w/v))

In 100 ml

diquafosol sodium	3 g
sodium hydrogen phosphate	0.1 to 0.5 g
sodium chloride	0.01 to 1 g
potassium chloride	0.01 to 1 g
sodium edetate hydrate	0.0001 to 0.1 g
sterile purified water	q.s.

Diquafosol sodium and other ingredients listed above are added to sterile purified water and they are mixed sufficiently so that this ophthalmic solution can be prepared.

Formulation Example 2: ophthalmic solution (3% (w/v))

In 100 ml

diquafosol sodium	3 g
sodium hydrogen hydrate	0.1 to 0.5 g
sodium chloride	0.01 to 1 g
potassium chloride	0.01 to 1 g

BAK-C_{12}	0.1 to 10 g
sodium edetate hydrate	0.0001 to 0.1 g
sterile purified water	q.s.

Diquafosol sodium and other ingredients listed above are added to sterile purified water and they are mixed sufficiently so that this ophthalmic solution can be prepared.

Formulation Example 3: ophthalmic solution (3% (w/v))

In 100 ml

diquafosol sodium	3 g
sodium hydrogen phosphate	0.1 to 0.5 g
sodium chloride	0.01 to 1 g
potassium chloride	0.01 to 1 g
BAK-C_{12}	0.1 to 10 g
citric acid monohydrate	0.0001 to 0.1 g
sterile purified water	q.s.

Diquafosol sodium and other ingredients listed above are added to sterile purified water and they are mixed sufficiently so that this ophthalmic solution can be prepared.

Formulation Example 4: ophthalmic solution (3% (w/v))

In 100 ml

diquafosol sodium	3 g
sodium hydrogen phosphate	0.1 to 0.5 g
sodium chloride	0.01 to 1 g
potassium chloride	0.01 to 1 g
BAK-C_{12}	0.1 to 10 g
sodium metaphosphate	0.0001 to 0.1 g
sterile purified water	q.s.

Diquafosol sodium and other ingredients listed above are added to sterile purified water and they are mixed sufficiently so that this ophthalmic solution can be

prepared.

Formulation Example 5: ophthalmic solution (3% (w/v))

In 100 ml

diquafosol sodium	3 g
sodium hydrogen phosphate	0.1 to 0.5 g
sodium chloride	0.01 to 1 g
potassium chloride	0.01 to 1 g
BAK-C_{12}	0.1 to 10 g
sodium polyphosphate	0.0001 to 0.1 g
sterile purified water	q.s.

Diquafosol sodium and other ingredients listed above are added to sterile purified water and they are mixed sufficiently so that this ophthalmic solution can be prepared.

INDUSTRIAL APPLICABILITY

Regarding Diquafosol ophthalmic solution comprising a chelating agent at a concentration of 0.0001 to 1% (w/v), formation of insoluble precipitates found in Diquafosol ophthalmic solution during storage of the solution, as well as deterioration of the filtration performance in the course of production (course of filtration sterilization), have been inhibited. Further, in Diquafosol ophthalmic solution comprising a chelating agent, reduction of eye irritation and enhancement of the preservative effectiveness have been confirmed, in comparison to Diquafosol ophthalmic solution comprising no chelating agent. Accordingly, the present invention has physicochemical properties that are stable during the courses of production and distribution as well as the course of storage by a patient, allows reduction of eye irritation, and also has excellent preservative effectiveness. In particular, since degradation of the filtration performance in the course of production (course of filtration sterilization) is inhibited, Diquafosol ophthalmic solution comprising a chelating agent can be subjected to efficient filtration sterilization in the course of production, thereby contributing to a decrease in production cost.

CLAIMS

1. An aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v) and a chelating agent at a concentration of 0.0001 to 1% (w/v).

2. The ophthalmic solution according to claim 1, wherein the chelating agent is at least one type selected from the group consisting of edetic acid, citric acid, metaphosphoric acid, pyrophosphoric acid, polyphosphoric acid, malic acid, tartaric acid, phytic acid, and salts thereof.

3. The ophthalmic solution according to claim 1, wherein the chelating agent is at least one type selected from the group consisting of edetic acid, citric acid, metaphosphoric acid, polyphosphoric acid, and salts thereof.

4. The ophthalmic solution according to claim 1, wherein the chelating agent is a salt of edetic acid.

5. The ophthalmic solution according to any one of claims 1 to 4, wherein the chelating agent is at a concentration of 0.0005 to 0.5% (w/v) in the ophthalmic solution.

6. The ophthalmic solution according to any one of claims 1 to 4, wherein the chelating agent is at a concentration of 0.001 to 0.1% (w/v) in the ophthalmic solution.

7. The ophthalmic solution according to any one of claims 1 to 4, wherein diquafosol or a salt thereof is at a concentration of 1 to 10% (w/v) in the ophthalmic solution.

8. The ophthalmic solution according to any one of claims 1 to 4, wherein

diquafosol or a salt thereof is at a concentration of 3% (w/v) in the ophthalmic solution.

9. The ophthalmic solution according to claim 1, wherein the chelating agent is a salt of edetic acid, the chelating agent is at a concentration of 0.001 to 0.1% (w/v) in the ophthalmic solution, and diquafosol or a salt thereof is at a concentration of 3% (w/v) in the ophthalmic solution.

10. The ophthalmic solution according to claim 1, further comprising a preservative.

11. A method for producing an aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v), comprising the step of mixing diquafosol or a salt thereof and a chelating agent in an amount that causes a final concentration of the chelating agent in the aqueous ophthalmic solution to be 0.0001 to 1% (w/v), to obtain an aqueous solution in which formation of insoluble precipitates is inhibited.

12. The method according to claim 11, further comprising the step of filtering the obtained aqueous solution through a filtration sterilization filter having a pore size of 0.1 to 0.5 μm.

13, A method for inhibiting formation of insoluble precipitates in an aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v), by adding a chelating agent at a concentration of 0.0001 to 1% (w/v) to the aqueous ophthalmic solution.

14. A method for reducing eye irritation caused by an aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v), by adding a chelating agent at a concentration of 0.0001 to 1% (w/v) to the aqueous

ophthalmic solution.

15. A method for enhancing preservative effectiveness of an aqueous ophthalmic solution comprising diquafosol or a salt thereof at a concentration of 0.1 to 10% (w/v), by adding a chelating agent at a concentration of 0.0001 to 1% (w/v) to the aqueous ophthalmic solution.