

Electrochemically activated water-based solution and use of the solution

An electrochemically activated water-based solution can be produced through electrolysis. A system for producing an electrochemically activated saline solution through electrolysis is known, for example, from EP 1 728 768 A1, wherein a water flow charged with a saline solution or with brine is fed to an electrolysis device. Through electrolytic decomposition of this briny water flow, one can obtain an electrochemically activated water-based saline solution exhibiting a relatively high content of active chlorine (AC, also called "free chlorine", to be determined, for example, by amperometric measurements) of up to 500 mg/l and a redox potential between +150 mV and +1,350 mV. Due to its relatively high content of active chlorine, this electrochemically activated saline solution can be used in a particularly favorable manner as a disinfectant, for example for degerminating water and/or water-based solutions. In addition, the chemically activated saline solution obtained according to the concept known from EP 1 728 768 A1 can, however, also be used in a particularly favorable manner, according to the indications made in WO 2009/013019, as a general disinfectant, i.e., for example, for work surfaces, floors, for sterilization purposes, in laundries or the like, or else as a carrier material in pharmaceutical substances.

Important parameters of the usability of electrochemically activated saline solutions for such applications are the content of active chlorine (or "free chlorine") and the pH-value. For a particularly high bactericidal or antibacterial effect, an as high a content of active chlorine as possible is desirable. In addition, especially in view of use as a disinfectant or for medical purposes, a particularly high storage stability is desired; even after a long storage of the material, the antibacterial effect should deteriorate only slightly. With the known materials and material compositions, it seems to be a particular problem to reconcile these parameters, i.e. the chemical reactivity, expressed in particular by the content of active chlorine, and/or the redox potential, the compatibility with other substances or biological systems, expressed in particular by the pH-value, and the storage stability, expressed in particular by the degradation in time of the materials and the increasing loss of their bactericidal or disinfecting effect.

The invention is, therefore, based on the problem to provide an electrochemically activated water-based solution, obtained by electrolysis, which exhibits a particularly high bactericidal or antibacterial effect and, at the same time, a particularly high storage stability, i.e. in particular even after a relatively long storage of, for example, more than two years.

This problem is solved by the invention by an electrochemically activated water-based solution, obtained by electrolysis of briny water in an electrolysis module comprising a plurality of electrolysis cells, each electrolysis cell comprising a first electrode space

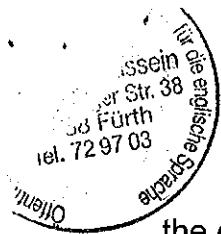
assigned to a first electric polarity and a second electrode space separated therefrom by a diaphragm and assigned to a second electric polarity, wherein the electrolyte is fed to the first electrode spaces of the electrolysis cells serially in the manner of a series connection.

Surprisingly, it has turned out that such a cascade-like flow through a plurality of electrode spaces of the same polarity in an electrolysis module with a plurality of electrolysis cells makes it possible to produce a highly efficient electrochemically activated solution, characterized by a particularly high content of active chlorine. The electrolysis module for producing the electrochemically activated solution should comprise several electrolysis cells, each with at least two electrode spaces, namely an anode space provided for the electric connection to the positive pole of an electrolysis voltage to be applied, and a cathode space provided for the electric connection to the negative pole of the electrolysis voltage. The provided cascade-like flow through a plurality of electrode spaces assigned to the same polarity through the electrolyte can be achieved by connecting the electrode spaces of the respective polarity, i.e. the anode spaces or possibly also the cathode spaces, serially or in the manner of a series connection, one behind the other, on the medium side, i.e. related to the flow guidance of the electrolyte.

A particularly high-quality electrochemically activated water-based solution as defined by the before-mentioned parameters chemical reactivity, neutral pH-value and storage stability can be obtained by providing in a particularly advantageous development a parallel connection, on the side of the medium flow, of the respective second electrode spaces of the electrolysis cells of the electrolysis module, in addition to the provided series connection, one behind the other, of the first electrode spaces of the electrolysis module, on the side of the medium flow. In other words: In an advantageous embodiment, the electrolyte is fed, on the one hand, to the electrode spaces of the first polarity in a cascade-like manner in the form of a series connection, and, on the other hand, to the electrode spaces of the respective other polarity, in the manner of a parallel connection. By sequentially flowing through the electrode spaces, the electrolyte is subjected in the individual electrolysis cells, step by step, to multiple treatment steps, one after the other, in the manner of a cascaded treatment, so that a multi-step and, thus, particularly extensive enrichment of ions in the electrolyte can be achieved.

To produce a highly efficient solution, characterized by a particularly high content of active chlorine, the medium-side parallel connection of the cathode spaces of the electrolysis cells and the medium-side series connection of the anode spaces of the electrolysis cells are provided in a particularly advantageous embodiment. Through such a cascaded treatment especially of the anolyte, a particularly extensive enrichment and upgrading of chloride ions in the anolyte can be achieved, so that especially in view of, for example, desired disinfection properties, a particularly high-quality anolyte can be produced.

The sequential treatment of the anolyte with parallel medium-flow guidance of the catholyte guarantees that during the electrolysis in the respective electrolysis cells, the concentration gradient between the ions in the anolyte, on the one hand, and those in the catholyte, on the other hand, viewed in flow direction of the anolyte, increases more and more from one electrolysis cell to the other. Thus, an increasing number of cells in



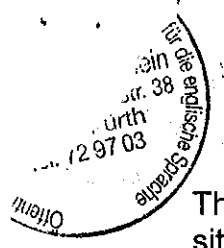
the cascade makes it possible to upgrade the ions in the anolyte with increasing intensity and, therefore, to provide an anolyte of increasingly "high quality".

An electrochemically activated solution with particularly favorable material properties with regard to the content of active chlorine and also with regard to the storage stability is obtained by the fact that in a particularly advantageous embodiment, the cathode spaces of the electrolysis cells are connected on the medium-outflow side with the anode space of the first electrolysis cell, viewed in flow direction of the anolyte. In this way, the electrolyte flowing out of the second electrode spaces of the electrolysis cells is fed to the first electrode space of the first electrolysis cell, viewed in flow direction of the electrolyte. Thus, in this particularly preferred medium-side connection, the outflow pipes connected to the cathode spaces of the electrolysis cells preferably lead to a collection point, where they run into a common pipe. This common pipe is connected on the outlet side to the first anode space, viewed in flow direction of the anolyte, of the cascade formed on the anode side by the electrolysis cells.

In another advantageous embodiment, only a partial flow of the electrolyte flowing out of the second electrode spaces of the electrolysis cells is fed to the first electrode space of the first electrolysis cell, viewed in flow direction of the electrolyte. Surprisingly, it has turned out that especially through a suitable adjustment and modification of the branching ratio in this area, i.e. by a specific adjustment of the share in the total flow of the catholyte - subjected as anolyte to further treatment - flowing out of the cathode spaces, essential parameters of the resulting final product, in particular the content of active chlorine, the pH-value and/or the storage stability, can be influenced. By a suitable adjustment of the branching ratio, it is in particular possible to change the flow rate and, thus, the dwelling and reaction time of the anolyte in relation to the catholyte, so that a particularly purposeful upgrading of the ions can be achieved. Furthermore, it is in this way possible to adjust the pressure ratios and/or the flow speeds, if required.

Surprisingly, it has turned out that the electrochemically activated water-based solution obtained through the above-mentioned electrolysis method exhibits particularly efficient bactericidal and disinfecting properties and, nevertheless, at the same time, an extremely low toxicity or incompatibility with human or organic tissue. In a particularly advantageous embodiment, the electrochemically activated solution obtained through the above-mentioned electrolysis method is, therefore, used in a pharmaceutical composition, in particular for treating inflammations, for germ reduction, for wound healing and/or for hygiene. The use in compositions for internal or external applications in humans or animals for the purpose of germ reduction in the blood, in mammary glands and/or in other bodily fluids in gall bladder, liver, bone marrow, glands or lymphs, etc., preferably in case of inflammations or ulcers, or else for purposeful killing of cells (e.g. tumor cells or virologically polluted cells) comes in particular into consideration.

It is also advantageous to use the solution in compositions for external application in humans or animals for the purpose of germ reduction, wound healing, prophylaxis, and hygiene, internally and externally on skins and/or mucous membranes, e.g. in case of colds, bowel diseases, such as, e.g., Crohn's disease, stomach ulcers, local antibiotics, or other suitable applications.



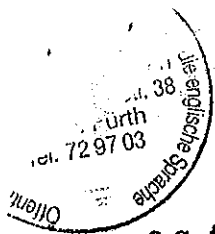
The electrochemically activated solution can be provided in the pharmaceutical composition as active component or substance, i.e. as active agent for achieving a desired pharmaceutical effect. In this context, a utilization as bactericidal or germicidal active agent comes in particular into consideration. In an alternative advantageous embodiment, the electrochemically activated solution can, however, also be an ingredient of a pharmaceutical composition in the manner of a carrier substance, whereby, due to the high bactericidal and disinfecting efficiency of the electrochemically activated solution provided as carrier substance, a protective effect for other substances or components present in the pharmaceutical composition as active agents can be provided. Thanks to its high bactericidicity and, at the same time, high storage stability, the electrochemically activated solution is suitable in a particularly advantageous manner as carrier substance for an active agent or active substance which for preservation or storage purposes shall be protected in a particularly efficient manner against any occurring pollutions through germs or the like.

It is particularly advantageous when the pharmaceutical composition is composed in the manner of a multi-component system, in which the active substance or active agent, on the one hand, and the electrochemically activated solution provided as carrier substance, on the other hand, are present in phases kept separately from each other. Advantageously, the phase containing the active agent or active substance properly speaking can be embedded in the other phase, formed by the electrochemically activated solution provided as carrier substance, or enclosed by that phase, in the manner of an emulsion, under formation of droplets. This phase separation guarantees, on the one hand, that the electrochemically activated solution, in view of its high chemical efficacy, will not destroy or impair the efficacy of the active substance actually provided as active agent. At the same time, on the other hand, the enclosing carrier material effectively prevents germs or impurities from penetrating into the droplets formed by the first phase, i.e. the active agent.

The electrochemically activated solution is suitable in a particularly advantageous manner as carrier substance in a pharmaceutical composition, in which prostaglandine tissue hormones, betablockers, a substance for reducing increased intraocular pressure, and/or an ophthalmic wetting and carrier agent (in particular a lubricant as eye-wetting agent, a glaucoma means or the like, preferably for treating conjunctivitis) are provided as active substance or active agent.

Due to its high chemical efficacy, in particular its particularly marked bactericidicity, and, at the same time, high compatibility with human tissue, the electrochemically activated solution obtained through the above-mentioned electrolysis method can also be used in a particularly advantageous manner as ingredient in a dermatological means and/or as disinfectant. A use in means for wound treatment, for ulcer treatment (diabetes), for body care, for sweat treatment, and/or for germ reduction on any skins or mucous membranes, in deodorants, pimple creams or lubricants, in means for hand disinfection and the like, comes in particular into consideration.

Furthermore, the electrochemically activated solution can also advantageously be used in the manner of a general disinfectant, either indirectly, i.e. as ingredient, or directly, for example for food preservation or other preservation purposes, e.g. of cut flowers or other substances decomposing through germs, as external application or as ingredient,



e.g. for washing fruit, for atomization in confined spaces, such as, e.g., storehouses, for germ reduction in industrial or apparatus processes, e.g. in air-conditioning installations, for germ reduction in plant breeding, e.g. in greenhouses, for drinking-water purification and/or for the control of epidemic diseases.

The advantages achieved with the invention consist in particular in that the electrochemical treatment of the electrolyte, in particular of the anolyte, in the manner of a cascade or in several successive stages, in a multi-part electrolysis module, makes it possible to adjust the ion exchange taking place during the electrolysis and, thus, the ion balance in the electrolyte, in such a way that the water-based solution electrochemically activated in this way has a particularly high content of active chlorine and, at the same time, a particularly good storage stability. The electrochemically activated water-based solution obtained through the above-mentioned method can have, for example, a share of active chlorine of 2000 mg/l or more, which can be measured, for example, through titration with iodine solutions, and a redox potential of, for example, 900 mV or possibly even more. Favored by an additionally obtainable pH-value of approx. 7, in combination with these parameters, and the, nevertheless, existing storage stability of two years or more, the electrochemically activated solution obtained in this way can also well be used in combination with other materials or active agents.

Furthermore, through an appropriate choice of the operating parameters in the electrolytic production of the electrochemically activated water-based solution, i.e. in particular through an appropriate choice of the amperage of the electrolysis current and the electrolysis voltage as well as of the velocity of the medium flow through the reactor and thus of the dwelling time of the media in the reactor, the pH-value of the final product, with high long-time stability, can be chosen almost freely.

An exemplary embodiment of the invention is explained in detail by means of a drawing, in which the figure shows schematically an installation for producing an electrochemically activated saline solution through electrolysis.

The installation 1 according to the figure is provided for producing an electrochemically activated water-based solution, in particular a saline solution, through electrolysis. For this purpose, the installation 1 comprises an electrolysis module 2, to which an electrolysis medium can be fed on the inlet side via a supply pipe 4. As electrolysis medium, softened water, mixed with brine or an water-based saline solution, is provided. For this purpose, the supply pipe 4 is connected on the inlet side to a water-softening station 6. For adding the brine to the softened water, a venturi tube 8 is connected in the supply pipe 4, said venturi tube 8 being connected, for its part, on the inlet side, with a brine container 10. Furthermore, an outlet pipe 12 branches off the supply pipe 4 after the water-softening station 6, via which supply pipe 4, the water flow from the water-softening station 6 can be discharged, during a startup phase of the installation 1, into the brine container 10, bypassing the electrolysis modules 2 of the following components. For changing over between these operating states and the continuous operating state as well as for dosing a predefinable quantity of brine into the electrolysis medium, appropriate valves 16, 18, 20 are connected into the supply pipe 4, the outlet pipe 12 as well as the brine-feeding pipe 14 running into the venturi tube 8, and, in addition, a throttle valve 22 is connected into the feeding pipe 14.

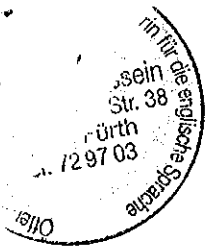
For discharging the electrochemically activated saline solution produced in the electrolysis module 2, an outflow pipe 24 is connected to the electrolysis module 2 on the outlet side. Said outflow pipe 24 runs into a reservoir 26 for the produced saline solution or the anolyte. For temporarily bypassing the reservoir 26 during the startup phase of the installation 1, a multiple-way valve 28 is, in addition, connected into the outlet pipe 24, the second output of said multiple-way valve 28 being connected to a drain pipe 30.

The installation 1 is designed for producing an electrochemically activated saline solution with particularly favorable properties, especially for use as disinfectant or antibacterial active agent, for example, in medical or pharmaceutical applications, in particular with a particularly high content of free chlorine of preferably more than 500 mg/l or possibly even more than 2000 mg/l, and, at the same time, a long storage life. To make this possible, the electrolysis module 2 is of a multi-component construction, comprising a plurality of electrolysis cells 40, only two of which are shown in the exemplary embodiment; of course, however, analogously to the following explanations, additional electrolysis cells 40 can be provided.

Each electrolysis cell 40 comprises an anode space 42 forming a first electrode space, and a cathode space 44 forming a second electrode space, separated from each other in each case by a diaphragm 46. The application of an electric voltage between an anode defining the respective anode space 42, on the one hand, and a cathode defining the respective cathode space 44, on the other hand, will then cause a migration of ions through the diaphragm 46 situated therebetween, so that an at least partial dissociation of the water contained in the electrolysis medium as well as an at least partial dissociation of the salt shares carried along in the form of brine will take place. Due to the electric charge of the ions in these materials, this ion-migration process will, as a consequence of the applied electric voltage, lead to an enrichment of Cl^- and OH^- in the respective anode space 42 and to an enrichment of H^+ and Na^+ in the respective cathode space 44. For the purpose of discharging, as required, hydrogen gas consequently enriched in the respective cathode space 44 or second electrode space, each cathode space 44 is connected with a degassing pipe 47. The latter forms a degassing module for the respective cathode space 44, possibly in combination with means for bubble generation or gas separation, such as, for example, swirlers or the like, arranged in the cathode space 44.

The desired properties of high quality of the electrochemically activated saline solution are achieved in the installation 1 in particular through a specific guidance of the media flows in the electrolysis module 2. For this purpose, a substantially parallel medium-flow guidance on the cathode side is combined with a substantially serial medium-flow guidance on the anode side in the installation 1 according to the exemplary embodiment, which is specifically aimed at providing an electrochemically highly activated anolyte. Alternatively or in case of a different objective of design, however, it would also be possible to combine a substantially parallel medium-flow guidance on the anode side with a substantially serial medium-flow guidance on the cathode side. Furthermore, additional combinations of these medium-side connections can also be provided.

In detail, a branch point 48 is provided in the supply pipe 4, in the installation 1 of the exemplary embodiment. From that branch point 48, feeding pipes 50 go off, which run into the cathode spaces 44 of the electrolysis cells 40 in the manner of a parallel



medium supply. On the outlet side of the cathode spaces 44, outflow pipes 52 are provided, which are joined in a collection point 54, so that on the whole a parallel connection of the cathode spaces 44 on the medium side is given.

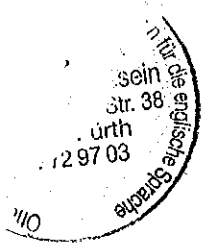
On the anode side, however, a series connection of the anode spaces 42 is provided for the anolyte. For this purpose, the anode space 42 assigned to the first electrolysis module 40, viewed in flow direction of the anolyte, is connected on the outlet side via an overflow pipe 56 with the inlet side of the following anode space 42. The latter, on its part, is connected on the outlet side to the outflow pipe 24, so that a series connection of the anode spaces 42 or of the anolyte, respectively, in the manner of a multi-stage or cascade-like design is given.

Furthermore, the installation 1 provides to feed the catholyte flowing out of the cathode spaces 44 as anolyte into the anode spaces 42 connected one behind the other. For this purpose, the collection point 54 for the catholyte is connected via an overflow pipe 58 with the anode space 42 of the first electrolysis cell 40, viewed in flow direction of the anolyte.

In addition, a discharge pipe 60 branches off the overflow pipe 58 in the collection point 54, through which a partial flow of the catholyte, whose quantity is adjustable via a throttle valve 62, can be supplied to a waste-water system or a collecting container 64. This arrangement makes it possible to feed an adjustable partial quantity of the catholyte flowing out of the cathode spaces 44 as anolyte to the cascade of anode spaces 42. In this way, it is possible to appropriately influence, among others, the individual reaction parameters, such as, for example, pressure and flow velocity in the anode spaces 42, and in addition, the quantity of catholyte produced in this application as "waste product" can be kept particularly low.

Furthermore, to check the material properties of the produced anolyte as well as to measure the quantity, a number of sensors, in particular a quantity sensor 66, a temperature sensor 68, a pH-value sensor 70, and a sensor 72 for measuring the redox potential, are connected in the outflow pipe 24.

As mentioned before, the installation 1 according to the figure is specifically designed for providing a particularly high-quality anolyte through a cascade-like series connection of the anode spaces 42 on the medium-flow side and a parallel connection of the cathode spaces 44 on the medium-flow side. An electrochemically activated solution of particularly high quality, with regard to its chemical properties, in particular the share of active chlorine and the redox potential, as well as with regard to its storage stability, can be obtained through the operation of the installation 1, for example, by feeding briny water through the supply pipe 4 via the branch point 58 in parallel into the cathode spaces 44. The concentration of brine in the softened water is adjusted by means of the throttle valve 22 and/or the venturi tube 8 in an appropriate manner and as a function of the desired content of salt or concentration of ions in the final product, and in the electrolysis module, the anolyte is guided at an appropriately chosen flow rate. After a dwelling time, the catholyte is charged with ions in the cathode spaces 44 via the respective adjacent diaphragms 46, the electrolysis voltage being applied between the respective anode and the respective cathode.



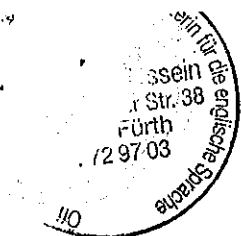
Then, the catholyte is discharged from the cathode spaces 44 and fed to the collection point 54. Behind the collection point 54, the catholyte is divided into two partial flows, a first partial flow of the catholyte of approx. 50% to 95% of the total flow, advantageously of approx. 90% of the total flow, being fed through the overflow pipe 58 to the anode space 42 of the first electrolysis cell 40, viewed in flow direction of the anolyte, whereas the second partial flow of the catholyte, corresponding to approx. 5% to 50% of the total flow, preferably approx. 10% of the total flow, is fed through the discharge pipe 60 to the collecting container 64.

Then, the first partial flow, starting from the anode space 42 of the first electrolysis cell 40, viewed in flow direction of the anolyte, is guided in a cascade-like manner as anolyte through the anode spaces 42 of the electrolysis cells 40, connected in series on the medium-flow side, and is thus subjected to several successive electrochemical activation steps, in the manner of a multi-stage treatment.

The electrochemically activated solution obtained in this way is in particular characterized by a relatively high content of active chlorine and, at the same time, a high storage stability. The salt content in the final products, i.e. in the produced anolyte as well as in the produced catholyte, can be adjusted, according to requirements, by a correspondingly adjusted dosing during the feeding of the brine from the brine container 10 into the flow of softened water (for example, at choice, as "low concentration" or else as "high concentration"). It is in particular possible to appropriately predefine the conductivity of the final product through appropriately adding the brine to the water flow; the conductivity can be adjusted for an anolyte of relatively low concentration of active chlorine to approx. 10 mS/cm and for an anolyte of relatively high concentration of active chlorine to approx. 18 mS/cm.

Afterwards, the "duration of treatment" of the anolyte, on the one hand, and of the catholyte, on the other hand, can appropriately be adjusted through an appropriate adjustment of the flow velocity of the media in the reactor, i.e. in the electrolysis module 2, enabling in particular to specifically adjust the pH-value of the final products. In this context, the operating temperature in the media flows, which arises as a function of the amperage of the electrolysis current, should not be chosen too high, in order to guarantee a high product quality. Both for an anolyte of low concentration and for an anolyte of high concentration, pH-values can be adjusted, preferably in the range of 7.0 to 7.6, whereby the arising anolyte can be a transparent, colorless liquid with a chlorine-based odor and a redox potential of, for example, 850 to 950 mV (measured potentiometrically). Preferably, however, redox potentials of more than 1500 mV, in particular also of more than 2000 mV, are also adjusted.

The content of active agent (or share of active chlorine), which can be determined by iodometric titration, for an anolyte produced according to the exemplary embodiment, amounts to approx. 600 to 800 ppm for an anolyte of low concentration (preferably used as disinfectant and characterized by a conductivity of approx. 10 mS/cm) and approx. 800 to 950 ppm for an anolyte of high concentration (preferably used as medical or pharmaceutical active agent and characterized by a conductivity of approx. 16 to 20 mS/cm).



In addition to these exemplary embodiments, the anolyte can, for example, also be produced with the following criteria and/or characteristic parameters:

- The electrolyte is characterized by a meta balance, solved in water, of ions of salt (Na, Cl), water (H_2O , OH, H_3O), ClO_x , and possibly Cl_2O_y , their acids and bases, their anions and cations and their solution species, which are mutually dependent.
- As a function of the adjustment of the operating parameters in the production process, in particular medium flow rates, operating voltages and currents, concentration specifications, values between, for example, 400 and 2000 mgAC/l, possibly even more than 2000 mgAC/l, can be adjusted for the content of active chlorine.
- The pH-value can be adjusted between 2 and 14, preferably, a value between 6 and 8 is adjusted.
- The conductivity can lie in the range between 14 mS (lower limit: 4 mS) and 25 mS and is preferably adjusted to a value in the range of 10 mS (surface) and 18 mS (isotonic) and 22 mS (pharmaceutical applications).

The salt content can be adjusted to a value in the range of 0.1 g/l to 15 g/l; preferably, a value in the (isotonic) range of 5 g/l to approx. 9 g/l is chosen.

List of reference numbers

1	Installation
2	Electrolysis module
4	Supply pipe
6	Water-softening station
8	Venturi tube
10	Brine container
12	Outlet pipe
14	Brine-feeding pipe
16, 18, 20	Valve
22	Throttle valve
24	Outflow pipe
26	Reservoir
28	Multiple-way valve
30	Drain pipe
40	Electrolysis cell
42	Anode space
44	Cathode space
46	Diaphragm
47	Degassing pipe
48	Branch point
50	Feeding pipe
52	Outflow pipe
54	Collection point



in the same phase or in a phase separate from the electrochemically activated solution.

8. A dermatological means, in particular for treating wounds, ulcers (diabetes) and/or other skin diseases, comprising an electrochemically activated solution of any of claims 1 to 5.
9. A disinfectant comprising an electrochemically activated solution of any of claims 1 to 5.
10. Use of an electrochemically activated solution of any of claims 1 to 5 in a pharmaceutical composition.
11. Use of an electrochemically activated solution of any of claims 1 to 5 in a disinfectant.

Abstract

Electrochemically activated water-based solution and use of the solution

An electrochemically activated water-based solution, obtained by electrolysis of briny water in an electrolysis module (2) comprising a plurality of electrolysis cells (40), shall exhibit a particularly high bactericidal or antibacterial effect and, at the same time, a particularly high storage stability, i.e. in particular even after a relatively long storage of, for example, more than two years. According to the invention, such a solution is obtained by electrolysis of briny water in an electrolysis module (2) comprising a plurality of electrolysis cells (40), each electrolysis cell (40) comprising a first electrode space assigned to a first electric polarity and a second electrode space separated therefrom by a diaphragm (46) and assigned to a second electric polarity, wherein the electrolyte is serially fed to the first electrode spaces of the electrolysis cells (40) in the manner of a series connection.