Physical and chemical properties of deionized water and saline treated with low-pressure and low-temperature plasma

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ABSTRACT Low temperature plasma, also known as cold plasma, has been used in many industries, including the synthesis of biomaterials, in order to improve the clinical efficacy of medical implants by a diverse modification of their surface.

The cold plasma process is characterized by a low degree of ionization at a low atmospheric pressure. In order to produce low-temperature plasma at first a compound is converted into a state of ionized gas and through the use of thermal energy in the form of direct or alternating current, radiation or laser.

The potential applications of low temperature plasma are due to the change of surface properties, including the electrochemical reduction and the nature of the chemical groups. Therefore, properties such as hardness, physical abrasion, corrosion, and the water absorption capacity and affinity to specific molecules are possible to be modified using cold plasma.

As a result of the substance undergoing low-temperature low-pressure plasma resonance, a substantial change occurs in its physicochemical properties, yet the effects of the application of cold plasma reactor for basic physicochemical properties of liquids such as water and physiological saline are unknown.

In this study, samples of physicochemical deionized water and saline were evaluated. The tests were carried out 7 days after deionization and / or operation of the low-temperature low-pressure plasma resonance in deionized water. An analysis was performed for the properties of water such as pH, conductivity, surface tension, density and dynamic viscosity. All measurements were performed at 24° C. Each measurement was repeated 6 times
for a sample for all tested sizes.

Introduction

Low temperature plasma, also known as cold plasma, has been used in many industries [1], including the synthesis of biomaterials, in order to improve the clinical efficacy of medical implants by a diverse modification of their surface [2].

The cold plasma process is characterized by a low degree of ionization at a low atmospheric pressure [2, 3]. In order to produce low-temperature plasma at first a compound is converted into a state of ionized gas and through the use of thermal energy in the form of direct or alternating current, radiation or laser [1, 3].

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Therefore, properties such as hardness, physical abrasion, corrosion, and the water absorption capacity and affinity to specific molecules are possible to be modified using cold plasma [4÷6].

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In this study, samples of physicochemical deionized water and saline were evaluated.
The tests were carried out 7 days after deionization and / or operation of the low-temperature lowpressure plasma resonance in deionized water.

An analysis was performed for the properties of water such as pH, conductivity,surface tension, density and dynamic viscosity.
All measurements were performed at 24° C.
Each measurement was repeated 6 times for a sample for all tested sizes.

The experimental part

Material
have been subjected to low-temperature plasma. 0.9% NaCl solution with a volume of 0.5 litre standard production of Fresenius Kabi Poland Ltd, and water deionized by reverse osmosis were supplied in containers of 0.2 litre.

Methods;

At the laboratory, deionized water and physiological saline were subjected to low-pressure low-temperature plasma with the use of a reactor, in the environment of residual gases, without the flow of other gases, without any change of parameters in the process.

The material was placed in sealed containers with a capacity of 0.5 litre (saline) or 0.2 litre (deionized water), subject to no rotation.

The impact of the plasma on the object was of a pulsatile nature with the synchronization network for 40 minutes.

The pH and conductivity tests were carried out by means of suitable measuring electrodes cooperating with the multifunctional SevenMulti ionic conductivity meter from Mettler Toledo.

The pH ratings were made using Clarytrode 120 electrode.

The conductivity measurements were made using the InLab740 conductivity cell from Mettler Toledo with an integrated probe for measuring the temperature of the tested solution.

The surface tension tests were performed using the STA1 tensiometer from Sinterface.

For density tests, a pycnometer by Gay-Lusaka was used.

The rheological measurements (measurement ofthe dynamic viscosity as a function of shear rate) was carried out using a RheoStress6000 rheometer from Haake, and a Thermo Scientific cone measuring system (C35/2o TIL) – plate (MP35) of outer solvent-trap.

The study of physicochemical properties of samples treated with low temperature plasma:

For all physiochemical measurements we used 3 specimens of water and 0.9% NaCl not treated with plasma process, and deionized water and saline, which underwent a low-temperature low-pressure plasma resonance (Tab.1).
The results were analyzed statistically using the student's t-test with the PQStat software. The results were presented as arithmetic means with the indication of the standard deviation (SD).
The results were considered statistically significant at $p < 0.05$. In order to determine the level of significance, the following indications were used: $p < 0.05$ * $p < 0.01$ ** $p < 0.001$ *** in order to compare the same type of liquid treated with and not treated with plasma

Summary of tested substances Symbol Substances

A	Deionized water
B	Deionized water + plasma
C	0,9% NaCl
D	0,9% NaCl + plasma

The results and discussion

The results of the measurements of selected physicochemical properties of deionized water and 0.9% NaCl showed differences between the two samples.

The pH of deionized water evaluated after 7 days from the deionization was about 5.4.

There was a significantly higher and statistically relevant pH value (7.85) for the deionized water after plasma process (Fig. 1).

The pH (5.9) of 0.9% NaCl was slightly lower than the 0.9% NaCl treated with plasma (pH 5. 99) – however, this difference reached a statistical significance (Fig. 1).

There was a significant difference in : the conductivity of deionized water was 13.53 mS/ cm-1, while of deionized water treated with plasma was 403 mS /cm-1 ($p < 0.001$) (Fig. 2A).

The conductivity of 0.9% NaCl (d=12.37 mS/cm-1) was lower than that of saline treated with plasma (d=13.47 mS/cm-1) (Fig. 2B).

In the study [9] we investigated the conductivity of deionized water treated with a variety of factors. Differences were obtained in the test volume, depending on the applied medium.

The electrolytic conductivity depends on the amount of the free ions in water and their ability to move.

The analyzed deionized water treated with plasma had a significantly higher surface tension (g=45 mN×m-1) in reference to the untreated deionized water (g=34 mN×m-1), while physiological saline treated with plasma was characterized by statistically significantly lower surface tension (g=31 mN×m-1) than 0.9% NaCl not treated with plasma (g=44 mN×m-1).

(For comparison, the surface tension of freshly distilled water according to the papers [10÷12] is respectively 72.44 and 72.49 mN× m-1.

Density and viscosity of the two tested fluids have not changed significantly under the influence of plasma (Figs. 4, 5).

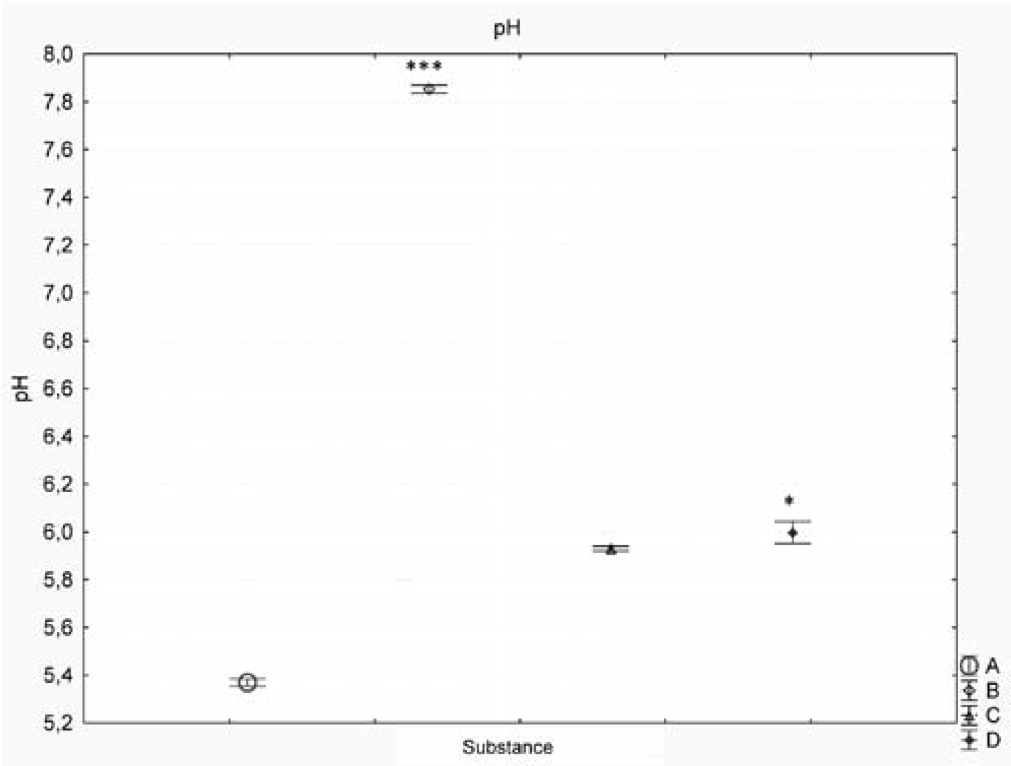

Fig. 1. pH values of tested substances

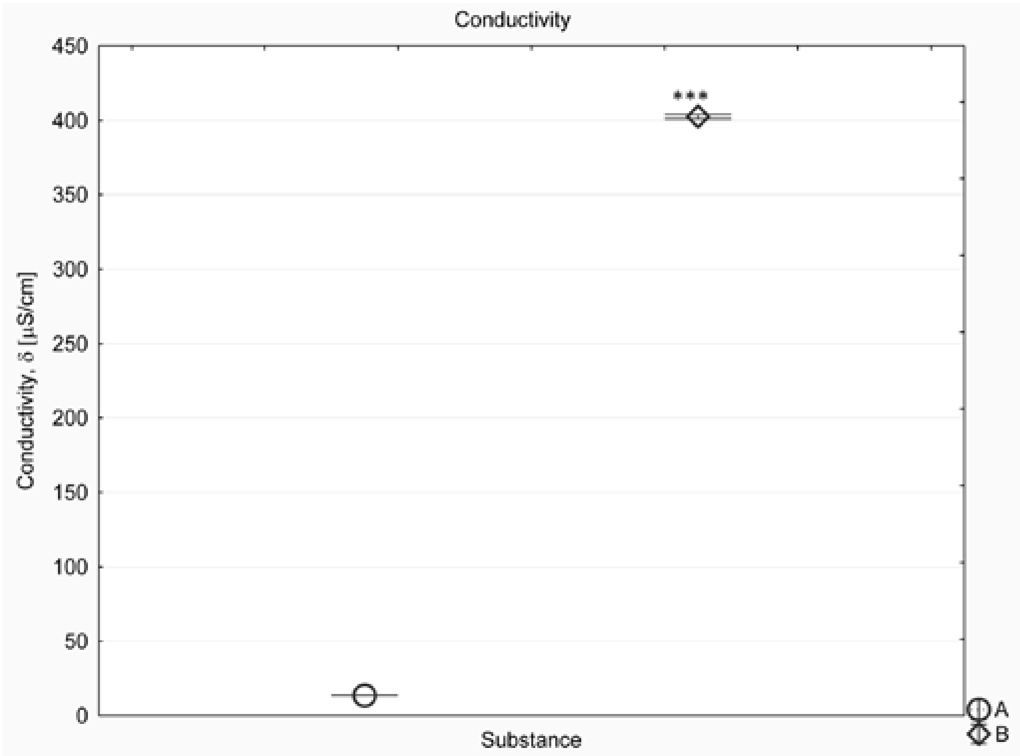

Fig. 2A. Conductivity of deionized water

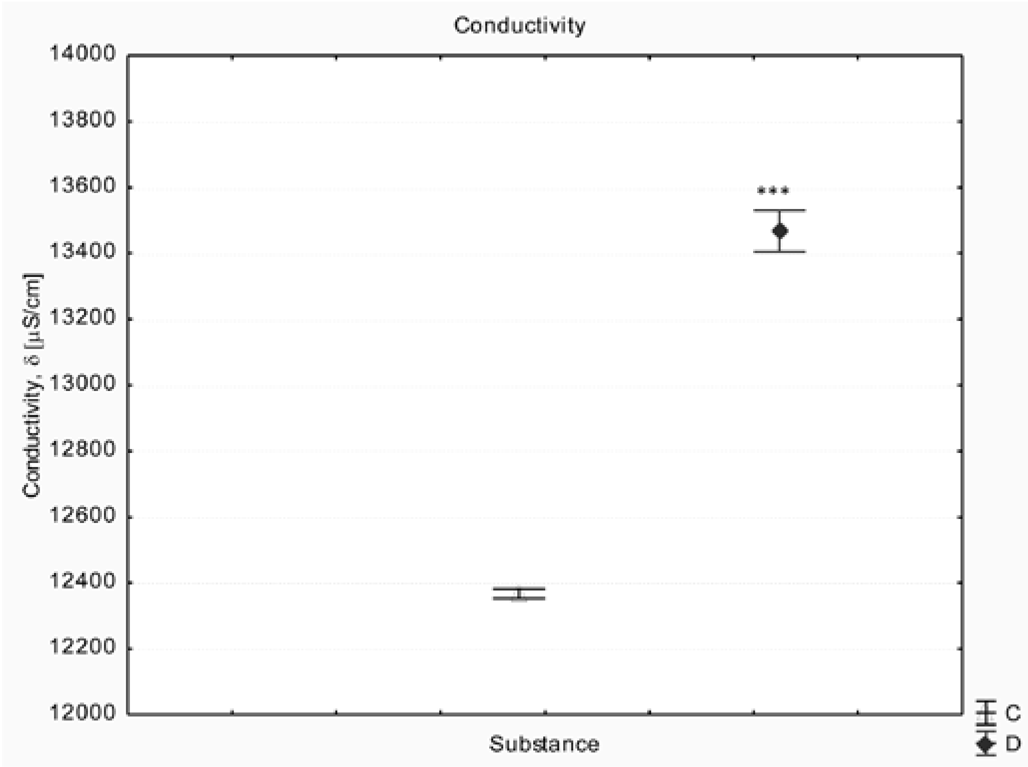

Fig. 2B. Conductivity of 0,9% NaCl

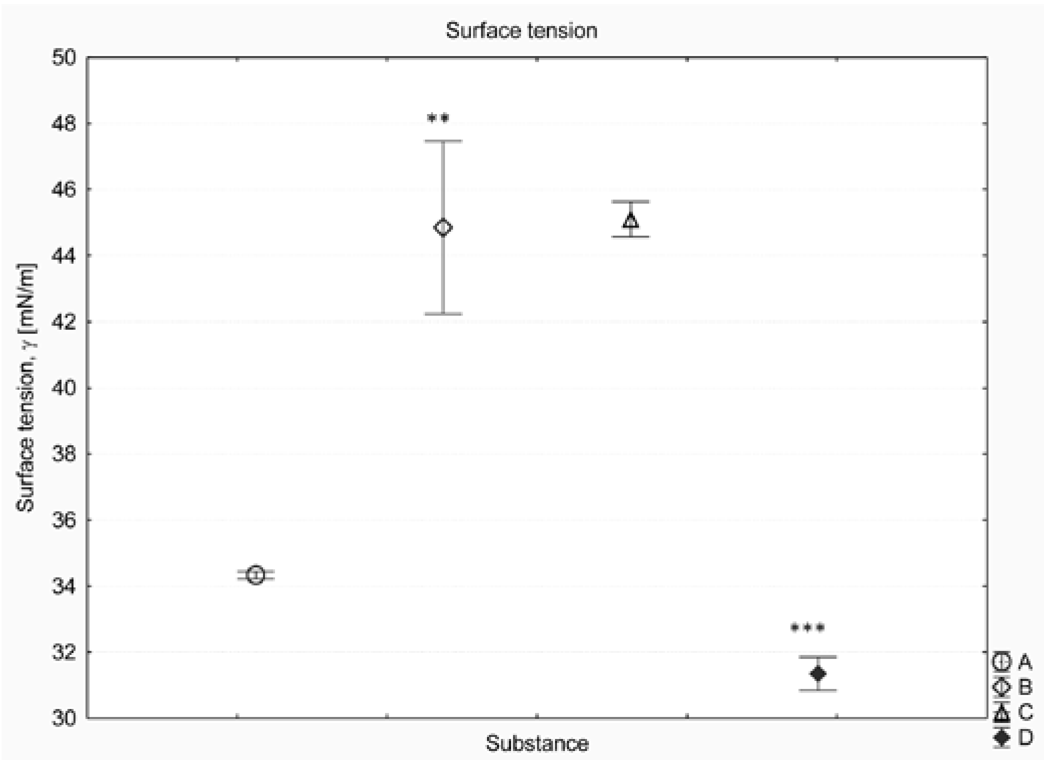

Fig. 3. Surface tension of tested substances

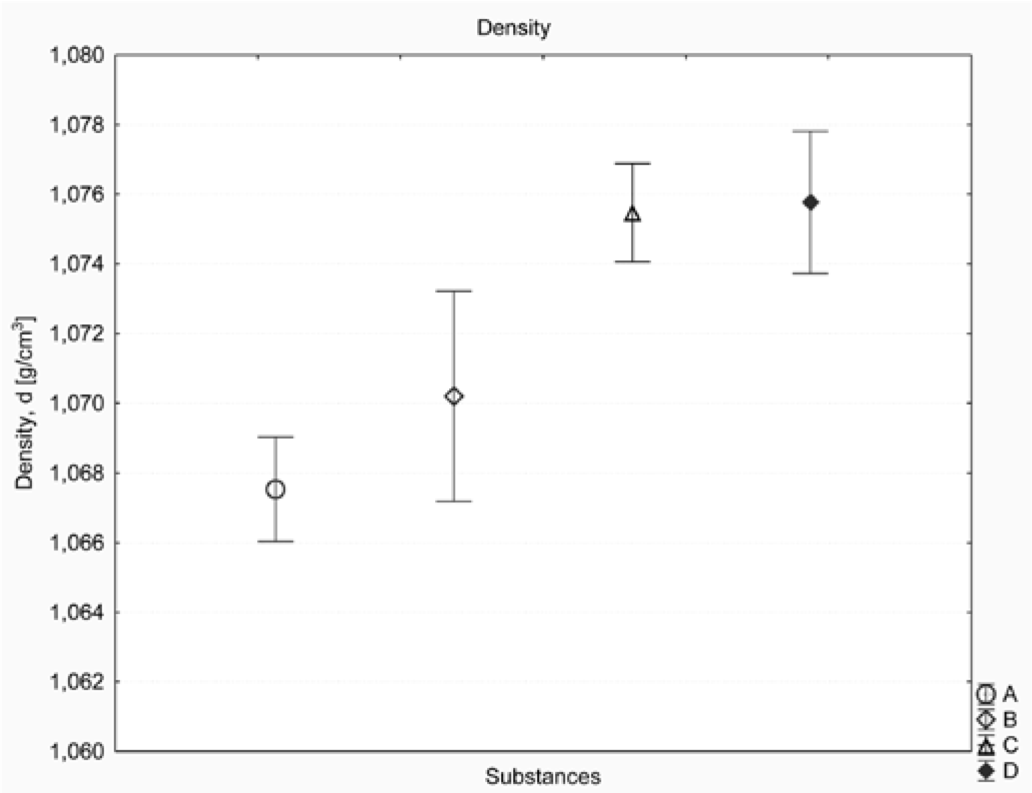

Fig. 4. Density of tested substances

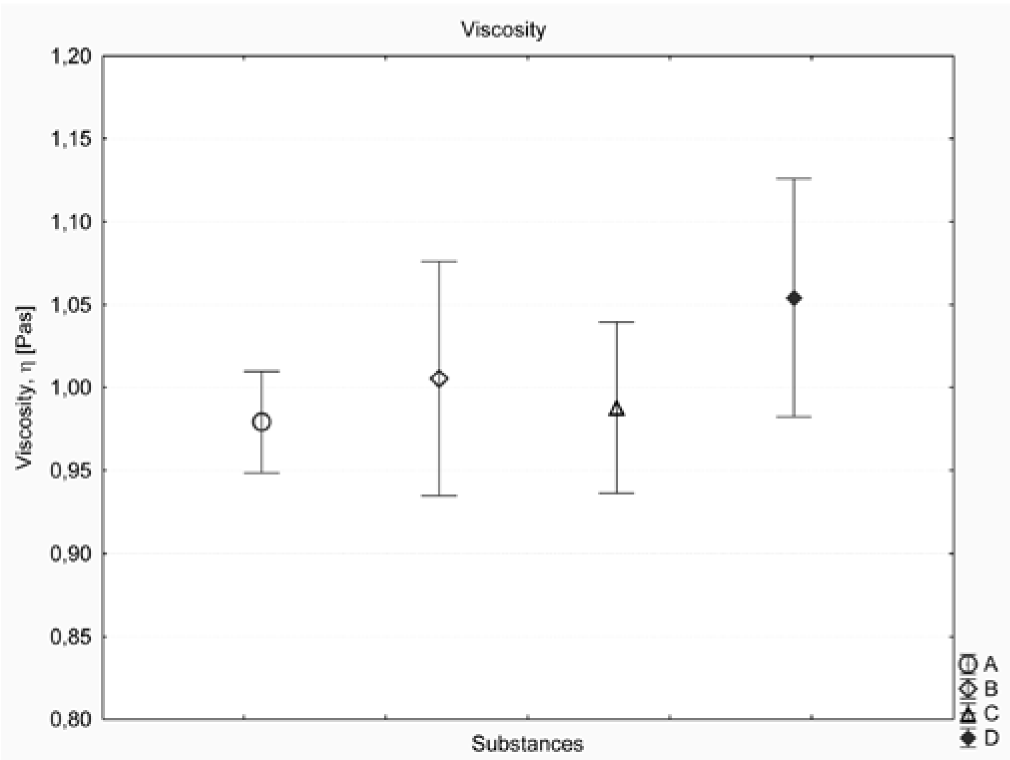

Fig. 5. Viscosity of tested substances

Summary and conclusions
The physicochemical studies have clearly shown that the deionized water and saline subjected to low-temperature low pressure plasma significantly changed their properties such as pH, electrical conductivity and surface tension as compared to their counterparts not treated with plasma.

The procedure of processing deionized water using a low-pressure and low-temperature plasmas have been submitted to patent admission

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