DECONTAMINATION EFFECTS OF THE CORONA DISCHARGE WITH PLANE TO BENT NEEDLE CONFIGURATION

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The dependency of the inhibition zone size on the needle geometry and angle between needle and plane in plane to needle electrode configuration was studied. Needles bent at angles from 0° (straight one) to 90° were used to study both negative and positive corona discharge treatment of the surface contaminated with *Candida albicans* yeasts.Inhibition zones shape and size changes were studied for positive and negative corona discharge. Ellipsoidal shape was characteristic for all treated samples in case of positive corona treatment, while the three-segment shape was observed for higher angles in case of negative corona discharge.

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INTRODUCTION

Nowadays well known decontamination effects [1], wound care and tissue treatment capabilities [2, 3] of low temperature plasma leads to study properties of many different decontamination techniques and devices. It is important to develop easy to use devices with the rapid decontamination effect and with large treated area.

Despite the fact that there are many articles about the atmospheric pressure nonthermal plasma (apNTP) decontamination, the exact decontamination mechanisms have not been precisely determined yet. The main decontamination agents are nitrogen and oxygen reactive species, charged particles, radicals, ozone, UV radiation. [1] However, contribution of the UV radiation is uncertain [4].

In this experiment dependency of inhibition zone size on the needle geometry, particularly on the needle bent angle, was studied. Simple point-to-plane electrode configuration device was used. The point electrode was realized by a bent needle. The plane one was an agar surface contaminated by *Candida albicans* yeasts.

1. EXPERIMENT

APPARATUS

A simple apparatus with a bent needle and the plane electrode as apNTP source was used. Point electrode was created by bending an ordinary intramuscular needle of 0.6 mm diameter. The plane electrode was realized by ion conducting cultivation medium (Sabouraud agar) in a Petri dish connected to electric circuit by copper stripe.

DC high voltage power supply (UTES HT 2103) with maximal voltage 10 kV was used. Ammeter and voltmeter were integrated parts of the power supply. A ballast resistor (10 MΩ) was used to limit current in the electric circuit. Experimental setup and electric circuit is depicted in Fig. 1.

The dependency of inhibition zone size and its spatial arrangement on bent angle of needle-shaped electrode was studied. Unbent needle, used as a reference was placed perpendicularly to the agar surface. Needle bent angles 30, 45, 60, 80 and 90° were chosen (Fig. 1). Time limit for each exposition was set to 10 min. The distance between plane and point electrodes was set to 7±2 mm to keep current at constant value of I_{mean} = 100 µA.

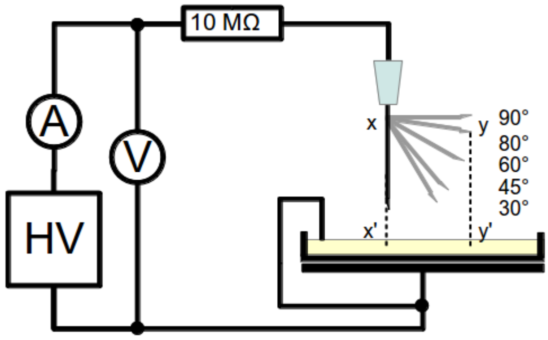

Fig. 1: Experimental setup – point-to-plane electrode configuration. Bending point x and needle tip y is projected to x' and y' point respectively

TREATED SAMPLES

To examine decontamination properties of apNTP *Candida albicans* yeasts were used. Initial solution was diluted (10^6 CFU/cm^2) in sterile water with ratios 1:100 and 1:1000 and spread onto cultivation medium. As soon as the agar surface got dry it was treated by discharge with unique polarity and bent angle. The samples were analyzed after overnight cultivation in thermostatic chamber at 37 °C.

Fig. 2: Negative (left) and positive (right) corona discharge. The parasite discharge at the elbow for 90° bent needle (left) and discharge at the needle edges for 80° bent needle (right)

DISCHARGE

The shape of visible discharge channel was changed by the needle geometry. The bell shape was typically formed in case of negative corona discharge, however the curved thin channel was observed in case of positive one. The parasite discharges at the needle elbow or edges could appear for large angles (Fig. 2). This effect was caused by the shorter distance between secondary ionization area and plane electrode surface in comparison to dominant one.

2. RESULTS

NEGATIVE CORONA

The area with visibly inactivated yeasts had a specific shape, that could be divided into three regions (Fig. 3). The inferior zone was the region under the needle and was decontaminated by invisible discharge over the whole needle length. The main inhibition zone was discovered under the needle tip. It was caused by the dominant discharge channel. The last one (the front zone) appeared for some angles in front of the main discharge zone. The decontamination of this region was probably caused by discharge products similarly as in case of indirect plasma treatment.

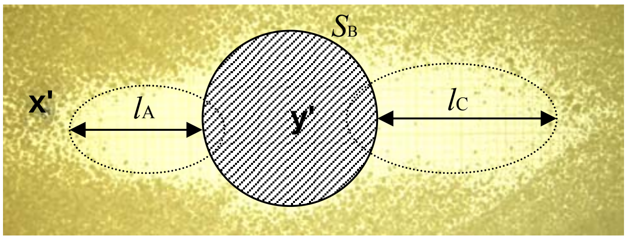

Fig. 3: The area, decontaminated by negative corona discharge with 80° needle-electrode bent angle. l_A– length of inferior zone, S_B – main inhibition area, l_C – length of front zone.

The shape of decontaminated area highly depended on a needle bent angle (see Fig. 4). The main inhibition zone seemed to be ellipsoidal for all needle-electrodes, but the inferior area (A) appeared only for angles 45° and higher.

The circular shape of total inhibition zone was appeared up to 30° angle. The inferior zone was undetectable for 30° and 45° needle bent angles, but started to be clearly visible for 60° and was maximal for 90° (see Fig. 4, blue line). The front zone started to be detectible for 45° and it was maximal for 60°.

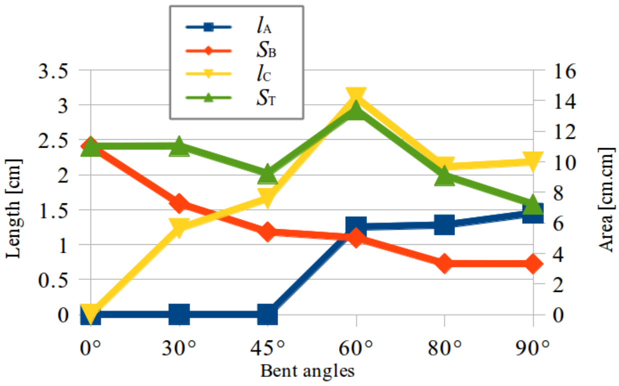

Fig. 4: Dependency of zones parameters on needle bent angle. l_A, S_B and l_C stands for inferior, main and front inhibition zone respectively. S_T means the total decontaminated area.

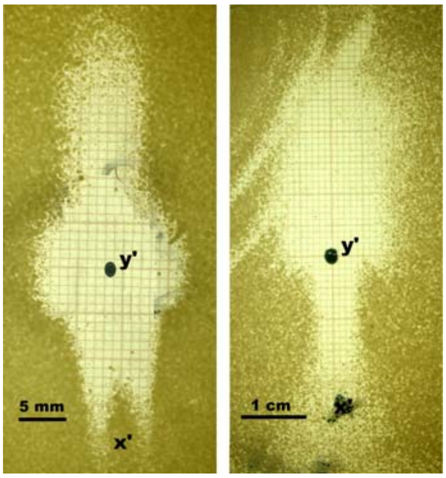

Fig. 5. Shapes of inhibition zones for negative corona discharge treatment for 80° (left) and 90° (right) angle.

POSITIVE CORONA

The positive corona discharge treatment created an area, that was eminently different compared to negative corona treatment. The inhibition zone was approximated by ellipse for evaluation. Ellipsoidal shape of the main inhibition zone was observed even for the unbent needle.

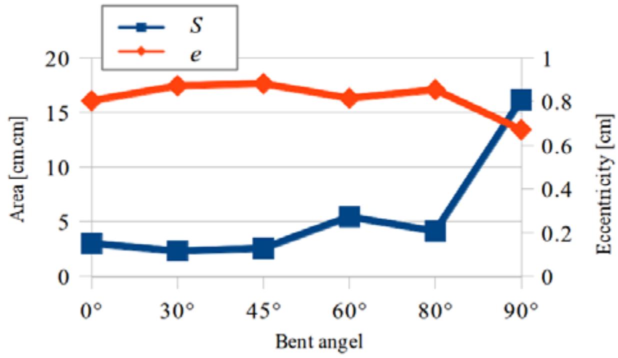

Fig. 6: Dependency of decontaminated area and eccentricity on needle bent angle for positive corona discharge.

Decontamination zone (expanding in front of the needle tip) increased with the needle bent angle (see Fig. 6). No inferior region was observed.

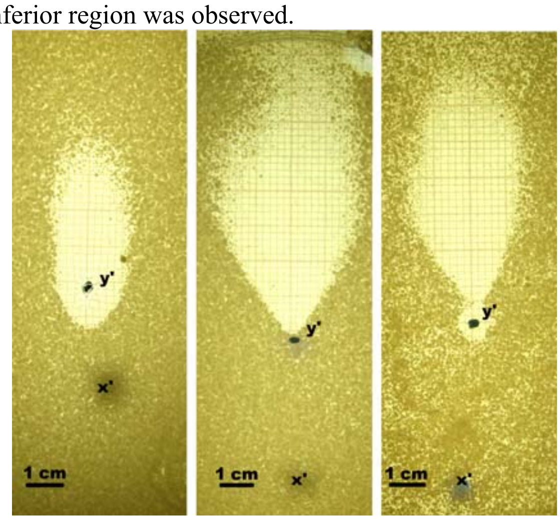

Fig. 7: The dependency of shape and size of inhibition zone on the needle bent angle for positive corona discharge (30°, 60° and 80°).

The parasite discharge effect was observed in 80° and 90° cases (see Fig. 7), when the high bent angle made the needle tip to be further from agar surface then the needle edges. These discharges treated a small circle area, that was not linked to the main inhibition zone (see Fig. 7, right).

The current of positive corona discharge was hard to stabilize for constant value of 100 μA due to deformation of agar surface by ionic wind.

CONCLUSIONS

The simple change of electrode geometry affected strong increase of the growth inhibition zone.

The area decontaminated by negative corona discharge could be divided into parts according to physical parameters of discharge. The positive corona decontaminated area was ellipsoidal for all treated samples. This geometry could be used to study indirect effect of corona discharge treatment.

Total area decontaminated by negative corona discharge maximum was observed for the needle bent 60° angle. The front decontaminated zone got its maximum at the same angle. The main inhibition zone right under the needle tip decreased with increasing angle.

Positive corona treatment caused increasing of the total decontaminated area while the radius ratio stayed at the same level.

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ОБЕЗЗАРАЖИВАЮЩИЙ ЭФФЕКТ КОРОННОГО РАЗРЯДА ПРИ КОНФИГУРАЦИИ ЭЛЕКТРОДОВ – ИЗОГНУТАЯ ИГЛА К ПОВЕРХНОСТИ

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Исследовалась зависимость размеров пораженной зоны от геометрии иглы, а так же от угла между иголочным и плоскостным электродами. Иглы согнутые под углами от 0 (прямая игла) до 90 градусов использовались для изучения влияния положительного и отрицательного коронного разряда на поверхность загрязненную дрожжами рода *Candida albicans.* Эллиптическая форма была характерна для всех образцов обработанных положительным разрядом. В случае использования отрицательной короны, зона состояла из трех сегментов. Это явление можно было особенно ясно наблюдать при использовании больших углов изгиба иголочного электрода.

ЗНЕЗАРАЖУЮЧИЙ ЕФЕКТ КОРОННОГО РОЗРЯДУ ПРИ КОНФІГУРАЦІЇ ЕЛЕКТРОДІВ – ЗІГНУТА ГОЛКА ДО ПОВЕРХНІ

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Досліджувалась залежність розмірів ураженої зони від геометрії голки, а також від кута між голковим та площинним електродом. Голки зігнуті під кутами від 0 (пряма голка) до 90 градусів використовувались для вивчення впливу позитивного та негативного коронного розряду на поверхню, забруднену дріжжами роду *Candida albicans.* Еліптична форма була характерна для всіх зразків, оброблених позитивним розрядом. При використанні від'ємної корони зона складалась з трьох сегментів. Це явище добре спостерігалося під час використання великих кутів вигину голкового електрода.