

EFFECT OF CHANGING THE APPLIED VOLTAGE ON BACTERIA IN PLASMA JET SYSTEM

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Abstract:

This study investigated the effectiveness of a homemade plasma system, the microwave-induced plasma jet (MIPJ), operating under atmospheric pressure (APPJ), in inhibiting bacteria that cause skin diseases. The system used argon gas and a voltage source of up to 2.4 GHz to generate a non-thermal plasma. The inhibition efficiency of the plasma was tested against gram-positive (*Staphylococcus aureus*) and gram-negative (*Pseudomonas aeruginosa*) bacteria. The bacteria were exposed to the plasma column at various voltages (165-185 V), with a gas flow rate of 10 L/min, a 60-second exposure time, and a 6 cm distance between the plasma and the bacteria samples. The plasma system effectively inhibited the growth of gram-negative bacteria (*Pseudomonas*) by adjusting the voltages during exposure. At 165 volts, the rate of bacterial inhibition was measured (0%), at 170 volts, the rate was (5%), at 175 volts, the rate was (10%), at 180 volts, the rate was (40%), at 185 volts, the rate was (50%), when exposed to the plasma system, gram-positive bacteria (*Staphylococcus aureus*) by adjusting the voltages during exposure. At 165 volts, the rate of bacterial inhibition was measured (10%), at 170 volts, the rate was (30%), at 175 volts, the rate was (40%), at 180 volts, the rate was (5%), at 185 volts, the rate was (35%), The MIPJ system proved to be an effective tool for treating different types of bacteria. The study emphasized the impact of voltage change on bacteria inactivation. It highlighted that an increase in the rate of voltage change and high-speed particle discharge could penetrate the external structure of bacteria, playing a crucial role in bacteria inactivation by the plasma jet

Keywords: *Staphylococcus aureus, Pseudomonas, plasma jet (MIPJ), inhibition, treatment, voltages.*

Introduction

Introduction

In 1927, the phrase was applied to an ionized gas; Langmuir was reminded of the ways in which red and white blood cells are carried by blood plasma, as well as the ways in which electrons and ions

are carried by an electrified liquid. Langmuir was studying the physics and chemistry of tungsten lamps with his colleague Lewi Tonks in an attempt to find a means to significantly increase the filament's lifespan (a goal he subsequently achieved). He also created the notion of plasma envelopes, which describes the stratified borders that arise between solid surfaces and ionized plasma. He also found that periodic fluctuations in electron density, which we now refer to as Langmuir waves, occur in specific sections of a plasma discharge tube. This was the genesis of plasma physics. Interestingly, Langmuir's research nowadays forms the theoretical basis for most plasma processing techniques for manufacturing integrated circuits. [1]

This plasma is defined as an assembly of charged particles, called electrons and ions, that collectively interact with forces exerted by electric and magnetic fields. [2]

For example, the substance in stars or nebulae is plasma. There is also man-made plasma on our planet, used daily in industrial and medical applications. [3]

Due to its noticeable effects on the samples utilized, plasma has been used in medical studies and has attracted a lot of interest, particularly in the fields of biological study. [4]

Gases used to generate plasma: Gas is an important part of plasma generation, and inert gas is usually used. The gas used in this study is argon gas and helium gas. They belong to the family of elements found in the last column of the periodic table of elements called “noble gases,” which include the elements helium, neon, argon, krypton, xenon, and radon. [5] The full electron valence shells of these elements prevent the formation of covalent bonds, and finding these gases in compound form remains rare. [6] The inability to form strong covalent bonds with other elements leads to the development of an identity for gases to be non-reactive, and the grouping of these gases under another term: inert gases. Although the term “inert gas” indicates that these gases do not have active properties, several cases have been observed in which these gases are capable of causing physical and biological effects. [7]

Argon gas is a monatomic gas that is colorless and odorless. It is considered the most abundant of the noble elements. Its atomic number is 18, and the density of argon is (1.784 g/L). [8]

Bacteria: Bacteria are prokaryotic, tiny, generally unicellular creatures that are ubiquitous in nature. Bacteria can be found in the human intestine, the ocean, and the soil. As opposed to eukaryotic cells, bacteria lack additional cellular organelles such as a well-defined nucleus that is membrane-bound. Bacteria can be deadly when they cause infection or helpful when they aid in the fermentation process. Most bacteria have a size of one micron. All bacterial cells have a lipid bilayer that serves as the cell membrane. The cytoplasm, which is inside each cell, is separated from the outside by the membrane. [9]

Staphylococcus aureus: Staphylococcus aureus is a gram-positive bacterium that appears under a microscope to be about 1µm in diameter. Its cells form clusters like grapes, as in Figure (1), as cell division occurs at more than one level. These bacteria are often found commensal with the skin, skin glands, and mucous membranes, especially in the nose of healthy individuals. Estimates indicate that 20-30% of the population carries these bacteria. [10] It is also called Staphylococcus aureus. There are some infections caused by Staphylococcus aureus, which include: skin infections (boils and abscesses) and impetigo. Staphylococcus aureus can also cause more serious infections, including meningitis (inflammation of the membranes lining the brain), osteomyelitis (infection of the bones and bone marrow), pneumonia (infection of one or both lungs), and septic phlebitis (infection of a vein) [11,12].



Figure 1: Staphylococcus aureus

Pseudomonas aeruginosa: Pseudomonas aeruginosa is a gram-negative bacterium that appears rod-shaped under the microscope. Pseudomonas aeruginosa can be found in soil, water, animals, humans, and plants. Some infections caused by Pseudomonas aeruginosa include bloodstream (bacteria), eye (bacterial keratitis), heart (endocarditis), respiratory tract (pneumonia), and urinary tract. [9]

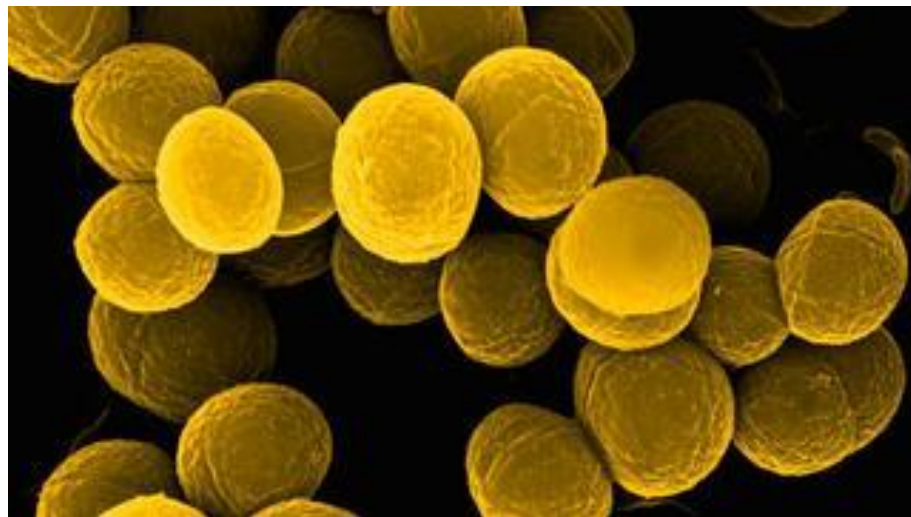


Figure 2: Pseudomonas aeruginosa

Plasma jet system: The microwave induced plasma jet (MIPJ) system consists of five main parts:

1. Microwave source
2. Waveguide
3. Plasma discharge tube
4. Ignition system
5. Flow meter

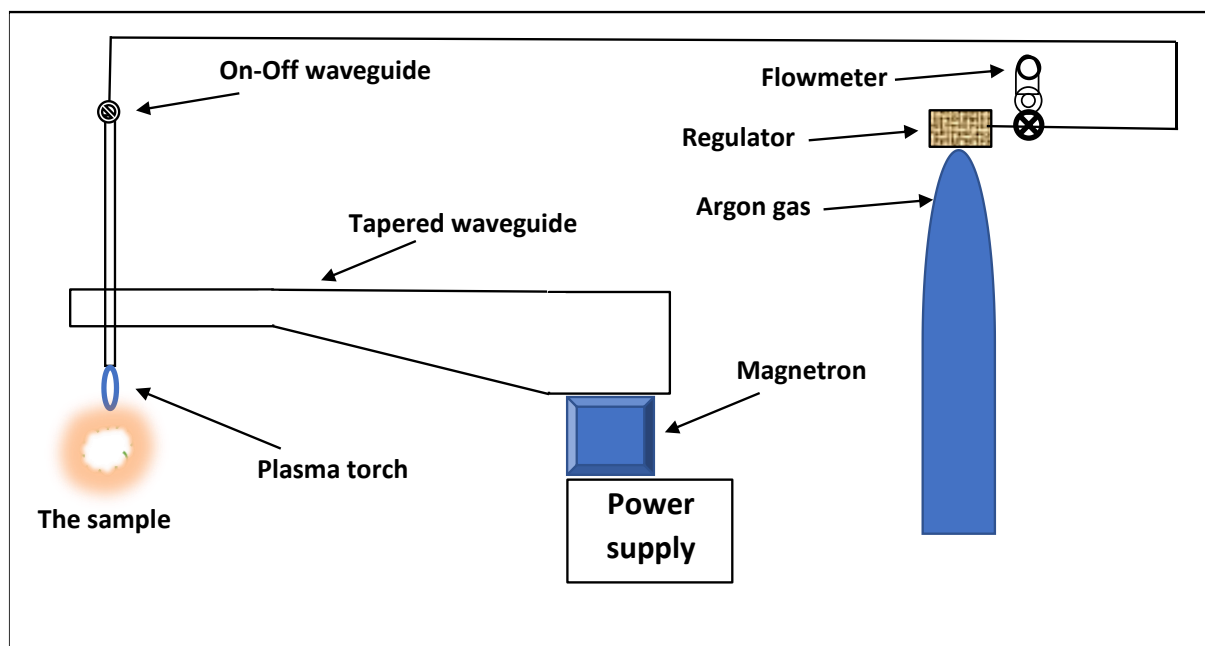


Figure 3: MIPJ

Plasma treatment sample: Bacteria were treated with plasma jetting using an argon gas flow rate of 5 L/min. The bacterial sample was treated for a fixed time of 60 seconds and variable voltages (165, 170, 175, 180, 185) volts for each group. After the treatment was completed, the plates were incubated at 37°C for 24 hours, and bacterial colonies were counted. Bacterial suspensions of *Staphylococcus aureus* and *Pseudomonas aeruginosa* at certain concentrations were used. The streak plate method was adopted as stated in Noelle et al., 2016 and Nussbaum et al., 2002.[13]

1. Preparing the culture medium for bacterial growth.
2. Prepare the bacterial inoculum for both models at a concentration of 1.5×10^8 bacterial cells per ml by mixing the bacteria with the physiological solution under sterile conditions.
3. Exposing bacterial models to plasma positives at different dimensions and voltages.
4. After the bacterial samples were exposed to plasma, they were cultured on petri dishes using the method of plotting on the plate.
5. It was incubated for 24-48 hours and then the results were read.

Control: The culture medium without bacteria served as a positive control, while bacteria not exposed to pathogens were grown on separate plates as a negative control.

Inhibition of pseudomonas bacteria by plasma: When gram-negative bacteria (*pseudomonas*) were exposed to the plasma system at a fixed time of (60 sec), a constant gas flow (10 L/min) and a distance of 5 cm, it was found that they inhibit the bacteria with changing voltages. At voltages (165) volts, the rate of bacterial inhibition was (0%), at voltages (170) volts, the rate of inhibition was (5%), at voltages (175) volts, the rate of inhibition was (10%), at voltages (180) volts, the rate of inhibition was (40%), at voltages (185) volts, the inhibition rate was (50%). As in the following figure.

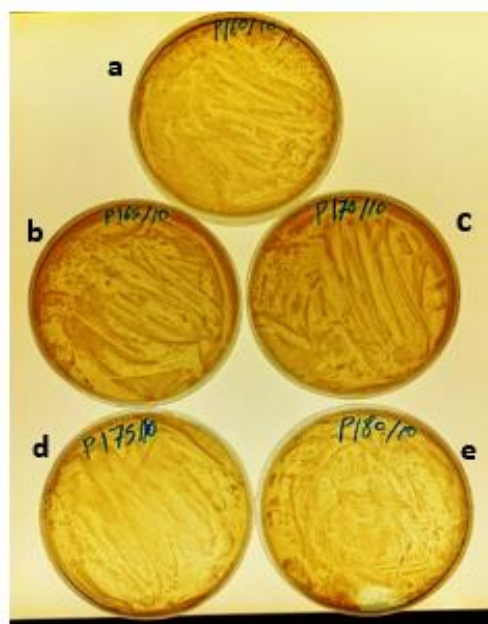
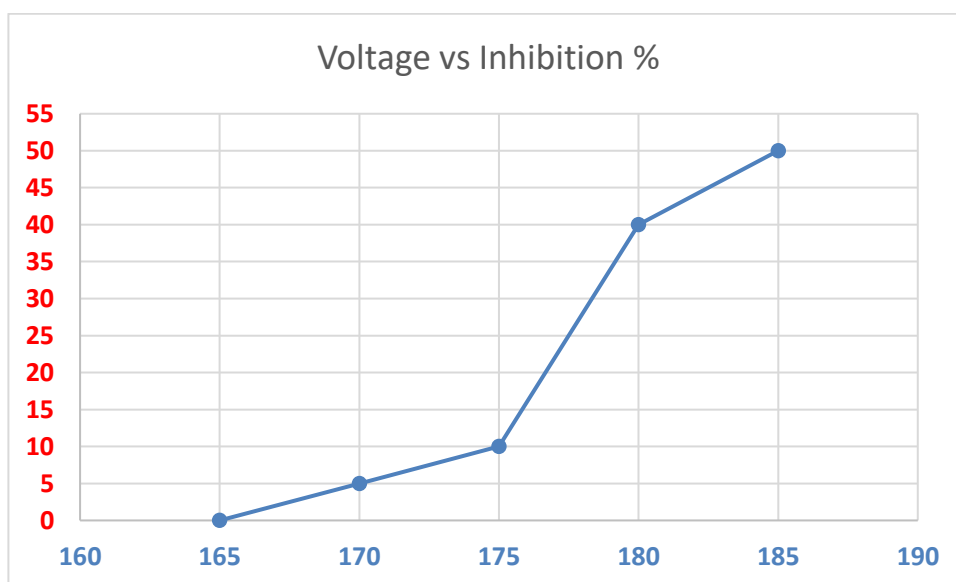


Figure 4: Pseudomonas bacteria after inhibition (a:165, b:170, c:175, d:180, e:185, v)



Inhibition of Staphylococcus aureus bacteria by plasma: When gram-negative bacteria (Staphylococcus aureus) were exposed to the plasma system for a fixed time of (60 sec) and a fixed gas flow as well (10 L/min) and a distance of 5 cm, it was found that they inactivate the bacteria with changing voltages. At voltages (165) volts, the inhibition rate was (10%), at voltages (170) volts, the inhibition rate was (30%), at voltages (175) volts, the inhibition rate was (40%), at voltages (180) volts, the inhibition rate was (5%), at voltages (185) volts, the inhibition rate was (35%). As in the following figure.

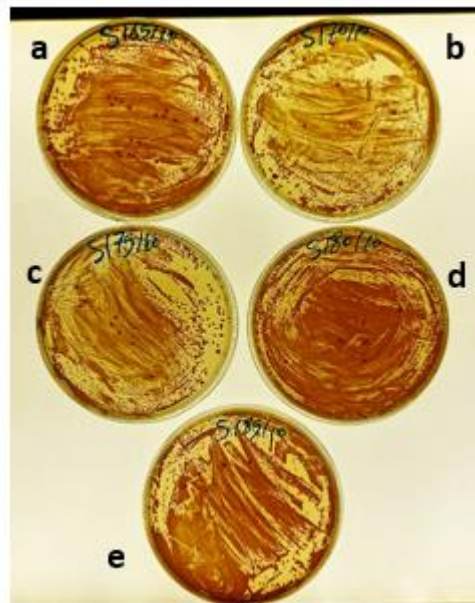
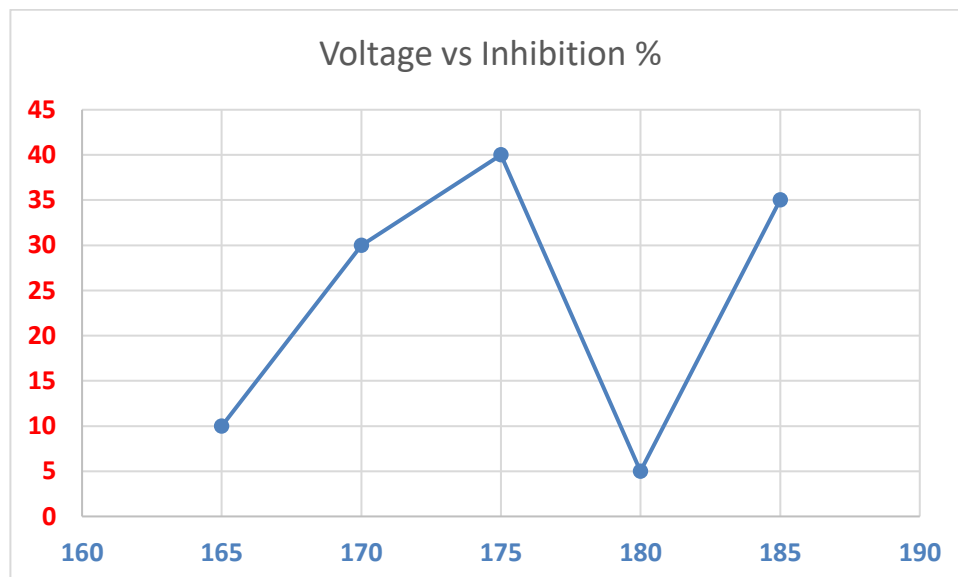


Figure 5: Staphylococcus aureus bacteria after inhibition (a:165, b:170, c:175, d:180, e:185, v)



Conclusion:

1. The MIPJ system is a useful instrument that may be applied to various bacterial species. Bacteria inactivation caused by plasma jet may be primarily influenced by the impacts of argon gas flow rate, as well as by increased gas flow rate and high-speed particle discharge penetrating the bacteria's outer structure [14].
2. It has been discovered that Staphylococcus aureus bacteria exhibit lower sensitivity to plasma jet treatment compared to Pseudomonas bacteria.

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