Ambient Decontamination by Non-Thermal Plasma in Atmospheric Pressure Air

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Abstract: In this research, Cold Plasma, which is non-thermal, is used as a weak gas and ionized, away from equilibrium thermally and dynamically. The needle plasma, a discharge in the non-thermal atmosphere is performed by different low-ionizing gases such as argon. The important properties of this plasma are that it works at approximately room temperature. Decontamination of surfaces contaminated and water of bacteria (Salmonella typhoid, pseudomonas aeruginosa) have been investigated in discharge of atmospheric pressure. The generator cold plasma as non-equilibrium. Water treated through the needle pole has led to the removal of biological contamination. The experiments provided to separate different plasma factors, oxidation stress measurements in cell membranes, and induced chemical changes in treated water to better understand plasma factors responsible for disabling microbes. Roots and reactive oxygen species appear to be biologically dominant agents.

1. Introduction.
The plasma described as ionized gas, containing free charge carriers (electrons and ions) [1]. The temperature of the electron is 1-10 eV, and the electrons are unable to transfer their entire kinetic energy from an electric field applied externally to the particles, so the gas remains non-thermal. Cold plasma is used as a weak gas and ionized, away from equilibrium thermally and dynamically [2]. The different energy states between electrons, ions and neutral molecules in non-thermal plasma [3]. Neutrals, ions remain relatively non-thermal, this provides the possibility of using this plasma in treat as biological tissues, heat-sensitive materials and biological materials [4]. Needle plasma is operate by different noble gas (He, Argon), the plasma does not cause any thermal damage to the materials that come into contact with it, it possesses important properties at its work at room temperature nearby. This property opens the possibility of using this plasma to process heat sensitive materials, and this type of plasma has the composition of one electrode, also this type developed for deactivation the bacteria [5].

2. Theory.

In non-thermal plasma, free radicals and reactive oxygen species play their primary and important role in this case, to the charged particles. Important mechanisms depend on the formation of non-thermal plasma, treated Microbiology, temperature and the environment (air, surfaces, and water). In cold air discharges (torch, Dielectric Barrier Discharge, corona), radicals and Reactive oxygen species (ROS) are identified as the dominant Deactivation agents[6]. Escherichia coli bacteria is a member of considered an opportunistic disease and consists of a large family of enterobacteriaceae bacteria. Which live in the intestines of animals especially people, and may affect stomach upset leading to diarrhea and urinary tract infections. In epithelial cells of the small intestine, salmonella typhi spreads and begins to attack these cells, lead in regional lymph nodes and the under-lying connective tissue, begins to multiply. S. typhi
bacteria are transmitted by water and food contaminated with faeces, so this bacteria is a cause of typhoid fever in people. The organism is typically transmitted by fecally contaminated water & food. When enters the bloodstream where it produces an acute germ and thus infects the bone marrow spleen as well as the liver, and ultimately gall bladder and kidneys. This stage, accompanied by high temperature and diarrhea, as figure 1; shows *Escherichia Coli* and *Salmonella typhi* bacteria [7].

![Figure 1. A.) Escherichia Coli on sheep blood agar B.) Salmonella Typhi on salmonella -shigella agar.][7]

3. Setup Experiential.
At 10 kHz frequency, use the high voltage power supply in our study to generate the discharge between two poles with air, one of which is surrounded by insulation. The discharge current and voltage are measured by oscilloscopes with high frequency. The non-thermal plasma system depends on the conventional plasma discharge which is mainly driven by the AC system. High alternating voltage (H.V) is alternating between two conductors one is surrounded by an insulator to prevent the arc transition. The discharge was generated by applied voltage *(0 to 5 kV)* (from peak-to-peak) between the grounding base that holds the sample and an insulated high-voltage pole.

Power is connected to stainless steel tube, current power supply and a variable voltage was used for samples. The barrier prevents flow of current between the electrodes, for this non-thermal plasma is created with active reactive concentrates and little gas heating, the distance varying from (1 to 5cm). In frequency *(15 kHz)*, that is to prevent transition to an arc and limit the current. Figure 2, shows the installation of experience in our work. The system consists of power supply of high voltage varying from *(0 to 20 kV)* related to a wire to the stainless steel tube. Other part of the system is gradually connected by a piece of mica to stainless steel to prevent the transmission of discharge to the catcher. Discharge occurs between the top surface and bottom surface of tube of the sample. The
distance at which discharge occurs was controlled from 1 to 5 cm. The diameter of the glass tube was 3 cm. According to the same procedure, all the treatments are at atmospheric pressure and room temperature.

![System Non-Thermal Plasma Needle](image)

**Figure 2.** System Non-Thermal Plasma Needle.

4. **Method.**
These samples were collected from water, sterilization tests were performed by drop from water sample and culturing bacteria before and after plasma needle treatment, while show growth of normal water bacteria (e.g. *Salmonella Typhi* bacteria) on the cultures of control sample cultured a large quantity of bacteria obtained from were cultured on artificial media (*salmonella –shigella* agar, Blood agar) to obtain bacteria colonies, carried out investigation of effects of non thermal plasma on bacterial cultures to determine size of disinfection, determine possible factors responsible. The prepared culture plates were exposure by plasma needle, they are then incubated for (24h).

5. **Results & Discussion.**
Optimum conditions was selected Voltage (2kV), frequency (15 kHz), distance (3.5 cm), time (10, 20, 30, 40 sec), and flow rates (1, 2) l/min, by using plasma needle for killing bacteria that inhabit from water. The initial study compared the individual susceptibility of two bacteria belonging to different species *E.Coli bacteria* and *salmonellae typhy bacteria*.

5.1. **Effect of flow rate on bacteria killing:**
At applied voltage (2kV) and distance (3cm), increasing with flow rate of argon gas shows increasing with killing percentage in *salmonella typhy* and *E. Coli* bacteria through increasing plasma treatment time as figures 3 & 4.
**Figure 3.** The relationship between killing percentage & plasma treatment time of salmonella typhi bacteria at distance 3 cm and Applied voltage =2kv at (a) Flow rate =1L/Min. and (b) Flow rate =2 L/Min.

**Figure 4.** The relationship between killing percentage & plasma treatment time of E.Coli bacteria at distance 3 cm and Applied voltage =2kv at (a) Flow rate =1L/Min. and (b) Flow rate =2 L/Min.
5.2. **Effect of distance on bacteria killing.**

At applied voltage (2kV) and distance (5 cm), increasing with flow rate of argon gas shows increasing with killing percentage in *salmonella typhi* and *E. Coli* bacteria through increasing plasma treatment time as figures 5 & 6.

![Graph](image)

**Figure 5.** The relationship between killing percentage & plasma treatment time of *salmonella typhi* bacteria at distance 5 cm and Applied voltage =2kv at (a) Flow rate =1L/Min. and (b) Flow rate =2 L/Min.
The effects of the increasing gas flow rate and reactive oxygen species penetrate inside the outer membrane of the bacteria which has important function of the deactivation of the bacteria by non thermal plasma. If bacteria are treated with increase gas flow rate, cell structure can be destroyed and the charges distributed on the cell membrane. The release of cytoplasm and the destruction of the cell wall will cause bacterial cell death due to high charged particles.

At operating condition that applied in this work, *Salmonella typhi* bacteria more sensitive to the non thermal plasma treatment than *E.Coli* bacteria; the partial deactivation time for *E. Coli* bacteria greater than *salmonella typhi* at time (40sec) of same condition. Focuses on determining plasma factors in deactivation the chemical effects induced in water (H$_2$O$_2$, NO$_2^-$ and NO$_3^-$) and their biocidal effects by coupling the electrical discharge, roots and reactive oxygen species (ROS) appear to be biologically dominant agents. Cold plasma produces long living as H$_2$O$_2$, and short lived as OH, ions, electrons and neutral particles. These are likely to be cytotoxic, stimulating low levels of cell membrane rupture and altering signaling pathways between cells. It is therefore possible to create a specific plasma to produce either charged or neutral particles to know the critical mechanism.
Destruction of the outer membrane of bacterial cells by charged particles which played an important role [8].

6. Conclusion.
The non-equilibrium cold plasma generator, water treated through the electrode needle, led to rapid bio-purification, in non thermal plasma; the inactivation depends on operating conditions such as treatment time, gas flow as well as distance.

Cold plasma produces long living as NO, neutral particles, short lived as OH, as well as charged particles (ions and electrons). These are likely to be cytotoxic, stimulating low levels of cell membrane rupture and altering signaling pathways between cells. It is therefore possible to create a specific plasma to produce either charged or neutral particles to know the critical mechanism, reactive oxygen species, radicals were found agents of atmospheric air discharges.

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