Experimental Comparison for effect of Positive and Negative Corona Discharge Plasmas on the Properties of Distilled Water

Ala' Fadhil Ahmed
Department of Astronomy & Space,
College of science, University of Baghdad,

Abstract

In this research, an experimental comparison of plasma positive and negative corona discharge has been investigated on distilled water at room temperature and atmospheric pressure at high voltage (0 -10 kV). By using a system of two electrodes, the first one is rod of 1 mm radius and the other is curved shape of 1cm radius. The result has shown that by using positive corona discharge plasma the power of hydrogen PH is decreased and the acid water is raised when increasing voltage and constant time of discharge (2 minutes of treatment). In addition, when the positive corona discharge duration (0-10 min) is increased with constant voltage at 5 kV , leads to same result above. When the negative corona discharge used with distilled water, the PH value increases and the water becomes base. The total dissolved solids (TDS) and electrical conductivity (EC) of distilled water in both plasma discharges (positive and negative corona) increase by raising the voltage processed and constant time as well, the discharge time increases when the voltage is kept constant.

Keywords: Plasma discharge, Positive corona, Negative corona, Distilled water.

1-Introduction

When high voltage is applied to electrodes to produce corona, streamer or spark discharge and light emission occur. An important reason for considering coronas is the production of ozone around conductors undergoing corona processes. A negative corona generates much more ozone than corresponding positive corona. There are different types of electrical discharges utilizing high voltage and ground electrodes submerged in water or high voltage electrode placed above the water surface with the ground electrode placed in water have been studied as possible methods for water treatment [1]. Plasmas produced by electrical discharges in liquids are finding wide applicability in a number of modern technology areas such as treatment of wastewater from a slaughterhouse by gliding arc humid air plasma [2]. Many scientists deal with various types of discharge configuration and several kinds of applied high voltage [3-9].

A corona discharge is an electrical discharge brought on by the ionization of a fluid surrounding a conductor which occurs when the potential gradient exceeds a threshold in situations where sparking is not favored. In corona discharge, a current develops between two high-voltage electrodes in a dielectric fluid, usually air, by ionizing the fluid so as to generate plasma around one electrode. This leads to the collection of electrons and ions made by stripping the electrons from atoms and electronic emission from the negatively polarized electrode. The ions generated are used as the charge carries to other electrode. Corona discharge usually involves two asymmetric electrodes, one highly curved (emitter, injector, or active conductor) and one of low curvature (collector) [10]. Electrical discharges in liquids have received particular attention because the non-thermal plasma generated by these discharges initiates various chemical and physical processes that can be potentially utilized in different environmental biological or medical applications. Depending on the type of the discharge and the input energy, these processes include high electric fields, ultraviolet radiation, overpressure shock waves, and, of particular importance, the formation of various reactive chemical species such as radicals (OH, H, O) and molecular species (H_2O_2, H_2, O_3) [11]. This paper is focused on the direct non-thermal plasma method of distilled water treatment based on a DC positive and negative corona discharge generated in air above the water surface.

2-Theory

- ***The PH value***

The acidity of water is measured in PH units. The PH value is a measure of the concentration of hydrogen ions, $[H^+]$ in the water expressed as a logarithmic value. The PH gives an indication of how acidic or basic the water is. Because the concentration of $[H^+]$ and $[OH^-]$ can vary over the very wide range of 10^0 to 10^{-14} it is convenient to use a logarithmic scale to express the concentration. For this purpose the PH function was introduced as:

$$PH = -\log [H^+] \qquad (1)$$

where $[H^+]$ is the hydrogen ion concentration expressed in moles/l. Because the PH scale is logarithmic, it means that a change of one PH unit is equal to a 10 times increase in $[H^+]$ concentration [12].

- ***Total Dissolved Solids***

Total dissolved solids (TDS) is a measure, in in parts per million (ppm) or the equivalent milligrams per liter (mg/L), of the amount of dissolved materials in the water. Ions such as potassium, sodium, chloride, carbonate, sulfate, calcium, and magnesium all contribute to the dissolved solids in the water. In many instances resource agencies use the terms TDS and salinity interchangeably, since these ions are typically in the form of salts. Measuring total dissolved solids is a way to estimate the suitability of water for irrigation and drinking. This is an important parameter for drinking water because high TDS values may result in a 'salty' taste to the water[13].

- ***Electrical conductivity***

Electrical conductivity is the ability of a substance to conduct an electrical current, measured in micro Siemens per centimeter (µS/cm). Ions such as sodium, potassium, and chloride give water its ability to conduct electricity. Conductivity is an indicator of the amount of dissolved salts in a stream. Conductivity often is used to estimate the amount of total dissolved solids (TDS) rather than measuring each dissolved constituent separately [13].

To convert EC (µS/cm) of water sample into approximate concentration of TDS (ppm) in the sample, a conversion factor is used. The factor depends on the composition of dissolved solids and can vary between 0.54-0.96. This value, 0.67 is used as an approximation [14].

$$\text{TDS (ppm)} = \text{EC } (\mu\text{S/cm}) \times 0.67 \qquad (2)$$

3- Experimental setup

The experiment setup consists of dc power supply of high voltage 10 kV, control resistance (10 kΩ), a cylindrical vessel made of teflon (radius 15 cm height 30 cm) and two electrodes of stainless steel. The first electrode of curved shape with radius 1cm lies in a center of vessel over the water surface. The other electrode is rod of radius 1 mm floated on the air (distance 5 mm from the surface of the water).

In this experiment, the chamber is filled with 250 ml of distilled water at room temperature 20 ^{0}C. The distance between rod electrode and the water surface is 5 mm. Figure (1) a schematic diagram of the experimental setup. By applying a different voltages of (0, 2, 4,…10) kV on the two electrode in both cases (positive and negative corona discharge) with a discharge time kept constant at 2 minutes of treatment, the measurement of PH, TDS and EC have been determined by using Ultrameter IITM 6P. (as shown in figure 2).

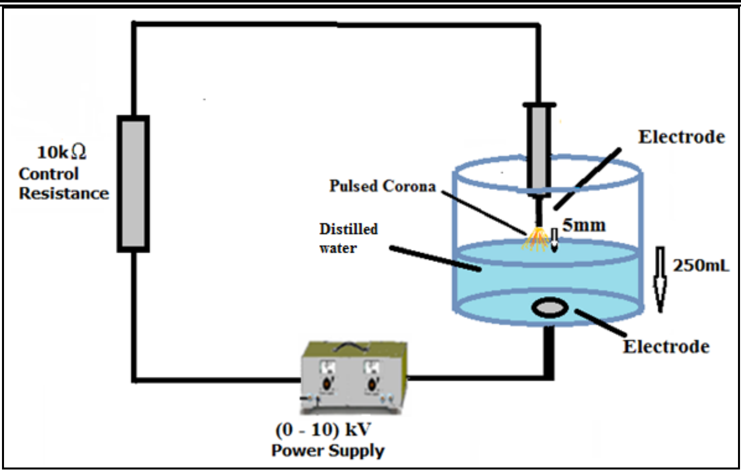
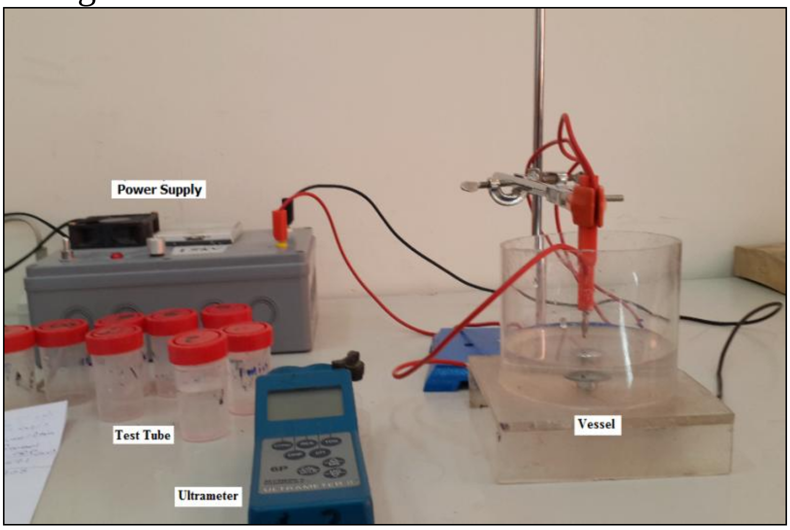


Figure 1 - Schematic diagram of the electrical discharge system.

Conversely, a constant voltage 5 kV has been applied and the discharge time is from 0, 2, 4… 10 minutes in both positive and negative corona discharges. The process occurring at the rod at positive corona discharge is illustrated in figure 2 which presents photographs of the electrode at 5kV voltages for distilled water.



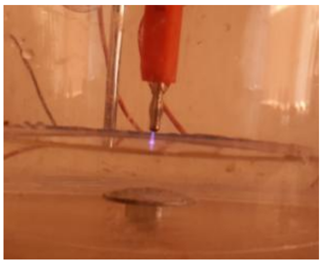


Figure 2 - The photograph of the electrical discharge system.

4- Results and Discussion

At positive corona discharge on distilled water when the external voltage is applied the behavior of TDS and EC curves of both cases is approximately voltage is increased (0, 2, 4,…, 10) kV and the time of discharge 2 minute of treatment results the following figures 3, 4 and 5 of the physical and chemical properties of the distilled water samples including PH, total dissolved solids (TDS) and conductivity (EC) respectively. Figure 3 indicates the PH value of the distilled water is decreases on positive corona discharge case which means that the acid water is raised [9]. On the negative corona, the PH value increase which means the base is raised. This behavior is due to, the same in the TDS and EC between both corona electrical discharge types when the voltage increases the TDS and EC increase. In addition, constant under external applied voltage less than 2 kV. While when the applied voltage is greater than 2 kV, the TDS and EC values increase (shown in figures 4 and 5).

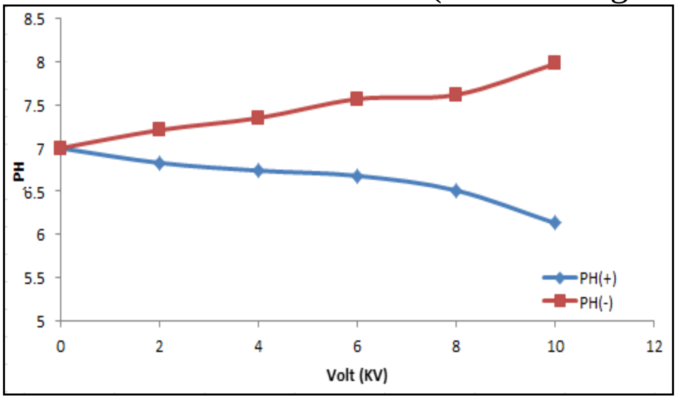


Figure 3 - Variation of the PH value for distilled water with the applied voltage of both positive (blue line) and negative (red line) corona discharges.

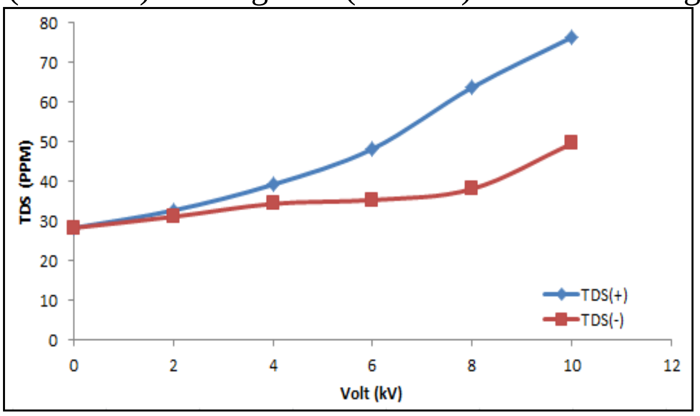


Figure 4 -Variation of TDS for distilled water versus the applied voltage of both positive (blue line) and negative (red line) corona discharges.

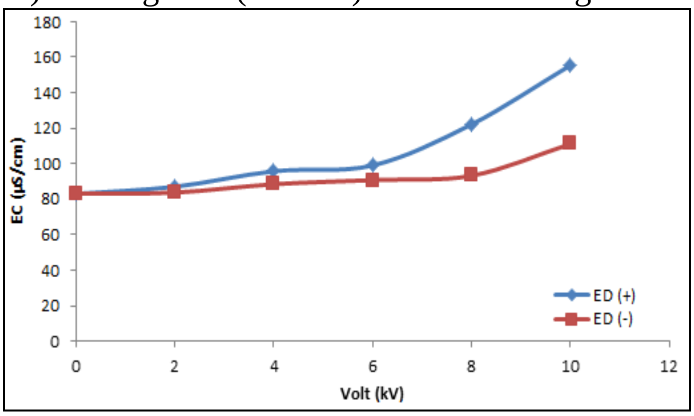


Figure 5 - Variation of EC for distilled water versus the applied corona voltage of both positive (blue line) and negative (red line) corona discharges.

Figures 6, 7 and 8 indicated that, the PH, TDS and EC respectively at corona positive and negative discharge on distilled water when external applied voltage is constant (5kV) and time of discharge is increased (0, 2, 4,…,10 minute of treatment). Figure 6 indicates the PH value of the tap water is decreased with increasing the applied voltage on positive corona discharge case which means that the acidity of water is raised. On the negative corona, the PH value increase which means the base is raised.
As for the total dissolved solids (TDS), their curve has the same shape as that of the conductivity showing that there's an increase of the ionic species in solution during treatment. An increase in conductivity with time of treatment was also demonstrated in the study of the distilled water (see in figures 7 and 8.

From the figures 4, 5, 7 and 8 the practical experiment of calculated TDS and EC value of distilled water can achieve approximately the theoretical relation of the following equation 2.

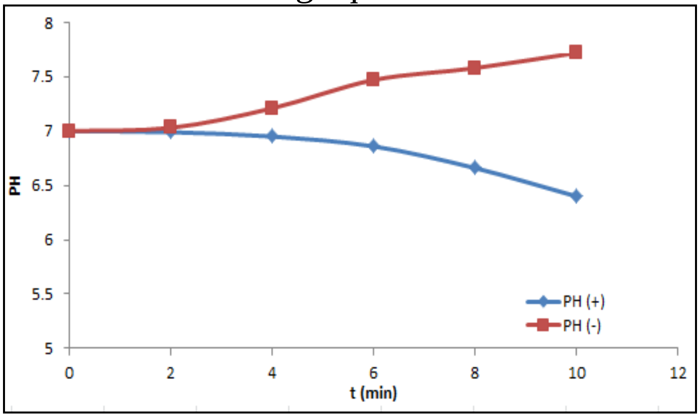


Figure 6 - The effect of corona discharge on the PH - time relationship of the distilled water in positive corona (blue line) and negative corona (red line).

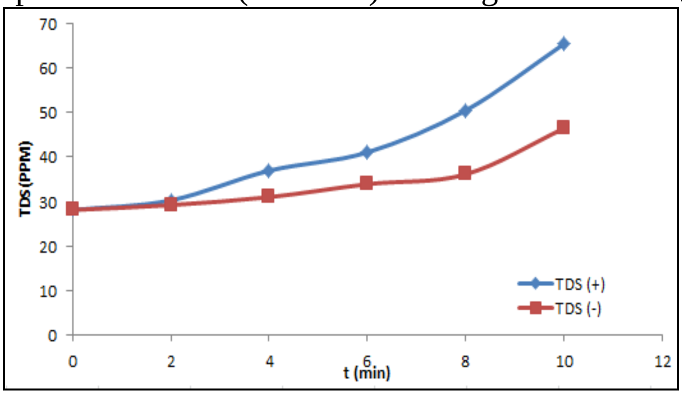


Figure 7 -The effect of corona discharge on TDS - time relationship of the distilled water in positive corona (blue line) and negative corona (red line).

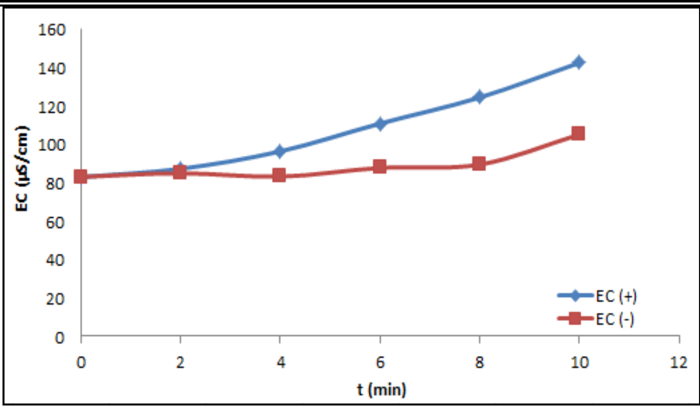


Figure 8 - The effect of corona discharge on EC - time relationship of the distilled water in positive corona (blue line) and negative corona (red line).

Figures 7,8 shows the continuously increasing evolution of total dissolved solids (TDS), in the same direction as conductivity. This feature may be related to the PH decrease and the matching increasing solubility of calcium carbonate since $Ca(OH)_2$ is used for concurrently with more expensive NaOH. Therefore, the growth curve from 10minutes showed an increase of ionic salts in solution [15].

5- Conclusions

According to above discussion, it can be concluded the following points:-

- PH value decrease and acid of distilled water increase when applied positive corona discharge while PH value increases and base water increases when applied negative corona discharge.
- The total dissolved solids and Conductivity increase in both of positive and negative corona discharges.
- In addition, the distilled water is affected by positive corona discharge more than negative corona discharge and this indicates that the amount of molecules of ionization of distilled water is increased at positive corona discharge.

References

1. Young S. M., Hyun T. A. and Joeng T. K. **2009**. **Treatment of Dyeing Wastewater by Using Positive Pulsed Corona Discharge to Water Surface.** Journal Plasma Science and Technology, 9(1), pp: 71-75.
2. Jourdin G., Serge A. Djepang, Paltahe A., Gaston P.,Samue L. and Danie N. **2014.Treatment of wastewater from a slaughterhouse by gliding arc humid air plasma: Chlorophyll degradation,** International Journal of Environmental Protection and Policy, 2(3), pp: 118-125.
3. Yang B., Lei L., and Zhou M. **2004**, **Effect of the Liquid Conductivity on Pulsed High-Voltage Discharge Modes in Water,** Chin. Chem. Let., 15(10), pp: 1215-1220.
4. Lukes P., Clupek M., Babicky V., and Sunka P.**2006. Erosion of Needle Electrodes in Pulsed Corona Discharge in Water**, Czechoslovak J. of Phys.56, pp: 916-924.

5. Qusay A. A., Falah A. H. and Fadhuil Y. H .**2011. Formation of Spark Corona Discharge in a liquid Electrical System.** Fundamental J. Thermal Science and Engineering, 1(2), pp: 101-105.
6. Sommers B., F. J., Babaeva N., and Kushner M**. 2011. Observations of Electric Discharge Streamer Propagation and Capillary Oscillations on the Surface of Air Bubbles in Water"**, J. Phy. D: Appl. Phys., 44, 082001, pp:1-6.
7. Miichi T., Hayashi N., Ihara S., Satoh S., and Yababe C.**2002**. **Generation of Radicals Using Discharge Inside Bubbles in Water for Water Treatment**, Report of Faculty of Sci. and Eng. Saga University, 31(1), pp: 1-5.
8. Sabooni M.,and Ghanbarzadeh J. **2007**. **Comparison of Tap Water, Distilled Water and Slurry Water on Surface Hardness of Gypsum Die**, J. Med. Sci., 7(8), pp: 1350-1353 .
9. Ariadi H., Reni D., Eka P. W. and Darwison**. 2013. Removal of Microorganisms in Drinking Water using Pulsed High Voltage"**, J. Eng. Technol. Sci., 45(1), pp: 1-8**.**
10. Qusay A. Abbas**.2013. Effects of Positive Corona Discharge on PH Value of Tap and Distilled Waters in Liquid system,** Journal of Al-Nahrain University , 16(4), pp:141-144.
11. Lukes P., Clupek M., Babicky V., and Sunka P. **2008. Pulsed Electrical Discharge in Water Generated Using Porous-Ceramic-Coated Electrodes**, IEEE Trans. on Plas. Sci., 36(4),pp: 1146-1147.
12. Frik S. **2006. Handbook For The Operation Of Water Treatment Works,** Editor:Water Utilisation Division Department of Chemical Engineering, University of Pretoria, TT 265/06 **.**
13. Muthulakshmi L. , Thillai P.A., Iavarasi R. and R. Selvanayagam R**. 2015. Hydrochemical trend of ground water – Rajapalayam town, Tamil Nadu, India**, J. Mater. Environ. Sci. 6 (4), pp: 1004-1008.
14. Safari D., Mulongo G., Byarugaba D. and Tumwesigye W. **2012. Impact of Human Activities on the Quality of Water in Nyaruzinga Wetland of Bushenyi District – Uganda**, Int. Res. J. Environment Sci. 1(4), pp: 1-6.
15. Paltahe A., Samuel L. and Jean L. Brisset. **2014. Pollutant abatement of unhairing-liming workshop of a tannery unit by non-thermal gliding discharge in air,** Int. J. of Environmental Protection and Policy, 2(6), pp: 200-204.

مقارنة تجريبية لتاثير بلازما التفريغ الهالي الموجبة والسالبة على خصائص الماء المقطر

آلاء فاضل احمد الراشدي
قسم الفلك والفضاء , كلية العلوم , جامعة بغداد

الخلاصة:
في هذا البحث اجريت مقارنة تجريبية لبلازما التفريغ الهالي عند الضغط الجوي في حالة التفريغ الهالي الموجب والسالب عند الفولتيات العالية (0-10 kV) في معالجة مياه المقطر عند درجة حرارة الغرفة باستخدام منظومة متكونة من قطبين ,احدهما ذا نصف قطر 1mm والاخر على شكل منحني نصف قطره 1cm . حيث لاحظنا عند استخدام بلازما التفريغ الهالي الموجبة نقصان في الاس الهايدروجيني PH وهذا يؤدي الى زيادة حامضية الماء عند زيادة الفولتية المسلطة وثبوت زمن المعالجة (2min) ونفس السلوك يحدث في حالة زيادة لزمن المعالجة (0- 10 min) وثبوت الفولتية 5kV بينما العكس يحدث عند المعالجة باستخدام ابلازما التفريغ الهالي السالبة حيث لاحظنا ان الماء يتجه نحو القاعدية اي زيادة في PH . في حين ان التوصيلية الكهربائية للماء (EC) و تركيز المواد الصلبة المذابة في الماء TDS في الكلا الحالتين (بلازما التفريغ الهالي الموجبة والسالبة) تزداد بزيادة الفولتة المجهزة وثبوت الزمن و ايضا في حالة ثبات الفولتية وزيادة زمن التفريغ.