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Numerical Evaluation of Physical Clogging System in Drip Irrigation Using Moringa Root Extract and Ozonized Water

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Abstract

Gravity fed drip irrigation system fitted with a clogged drip line was assembled with the intention of investigating the ability to remove, inhibit and clear clogging resulting from continuous usage of the drip line over the year. Phytochemicals extracted from Moringa root and tested to have a coagulating effect like Alum. Ozonized water was produced from an ozone generator while the Hydrochloric acid was sourced from local sources. These three solutions were used in flushing the gravity-fed drip irrigation setup to investigate their effect on the major drip system evaluation parameters like Average emitter discharge rate, Relative emitter discharge, Standard deviation of emitter flow rate, Coefficient of Variation of Emitter Flow, Statistical Uniformity, Emission Uniformity and Uniformity Coefficient. The result shows that Moringa Root Extract and Ozone water has the ability to remove and inhibit biofilms and can be used as anti-clogging agents for the treatment of emitters in drip irrigation systems used in agriculture and/or domestic landscapes. The use of these natural coagulator against biofilms and biological control of pathogenic microorganisms in drip irrigation systems may further be investigated.

Keywords

Numerical, Evaluation, Standard Deviation, Coefficient of Variation, Uniformity, Moringa, Emission

1. Introduction

Drip irrigation (trickle irrigation) is a type of micro-irrigation system which involves applying water to the soil at a very low rate (2 - 20 liters/hour) through a small fitted device called an emitter or dripper. It's a controlled system that saves water and nutrients by allowing water to drip slowly at low pressure to the root zone of the plants. It is a system that delivers a small quantity of water at a specific time. Because of environmental consequences and limited water resources common to irrigation systems, drip irrigation technology is getting more attention, particularly with high-value cash crops such as greenhouse plants, ornamentals, and fruits and it's playing an important role in agricultural production. However, clogging of the emitter has often been recognized as a challenge and one of the drip irrigation system's most important concerns is low system performance and water stress for the non-irrigated plants as opined by [1].

According to [2] the proliferation of bacteria can trap some solutes such as calcium bicarbonates or mineral particles in suspension in irrigation water. Biofilms are generally a collection of one or more types of microorganisms that can grow on many different surfaces. Therefore, for the smooth and efficient operation of a drip irrigation system, there must be deliberate science and engineering approaches to stern the menace of these organisms for a sustainable yield.

The demand for irrigation water is ever increasing as many nations' sources of supply for these purposes are more and more under pressure to meet other needs of domestic, power, and industrial sectors. With the challenges of setting priority for water needs, many countries are beginning to explore areas of food production throughout the year to meet the ever-increasing population by adopting the drip system of irrigation that uses less water to grow more food.

However, because of some human activities and environmental challenges, many sources of water are either polluted or infested with biofilms because of the favorable growth conditions and this sometimes creates difficulties in the efficient distribution of irrigation water on the field. To this end this paper aimed to investigate Moringa oleifera root extract, ozonized water, and Hydrochloric acid that can be used to inhibit and remove biofilms in emitters of the drip system and evaluate the effect of Moringa oleifera root extract, ozonized water, and hydrochloric acids on the drip evaluation parameters such as an average of the emitter discharge, the relative discharge of emitter, the standard deviation of emitter flow rate, the emitter variation coefficient, emitter statistical uniformity, uniformity of the emitter emission and coefficient of the emitter uniformity and compare the anti-clogging effect of moringa oleifera root extract, ozonized water with the hydrochloric acid treatment to determine the best treatment.

System Design Criteria and Challenges

According to [3] a well-designed irrigation system should focus on applying water uniformly and in a timely manner on the field to avoid losses, soil destruction, and other mineral resources. Certain criteria are important in designing a standard irrigation system which are vital to make sure that the volume of water supplied at a determined rate is absorbed without runoff considering the soil and water characteristics. The following is for designing the system:

System should be capable of delivering and applying the volume of water required by the crop.

1) Application rate should not be higher than the soil maximum allowable infiltration rates, knowing well that excess application may lead to erosion, water loss, and likely the sealing of the surface.

2) The quality of water to be supplied and its capacity should be determined and recorded.

3) Necessary climatic data (precipitation, wind velocity, temperature, and humidity, topography) and field layout information should be obtained.

4) Farmer's priorities in the methods of irrigation, available time for the operation, the availability and the cost of labor, required cultural practices, and the management skills must be noted for the selection and planning of the type and method of irrigation.

5) The texture of soil and the maximum infiltration rate allowed for the soil need to be noted for proper design and management.

6) Soil available water holding capacity, and the crop rooting depth must be known for planning and designing the system.

Generally, drip systems emission devices in use are normally the ones that are either in-line or the on-line drippers (externally fixed online). Application of water is done through the emitters or micro-spray heads along the sub-main also known as lateral in a drip system. The emitter is the outlet device controlling the water released. From the dripping point, water moves through the soil by both capillary and gravity forces to areas with higher water tension.

The volume of wetted soil depends on the characteristics of the soil, irrigation schedule, discharge from emitters, the spacing between the emitters, and their number. Spacing and the size of crops irrigated and the characteristics of the soil determine the number and spacing between the emitters as opined by [4].

High-value horticulture and crops depend heavily on a drip irrigation system due to high valued features. Therefore to succeed in operating any drip irrigation systems, adequate maintenance is required by [5]. The maintenance methods by different operators had never been the same considering:

1) Different system design layouts by various manufacturers

2) Variation in the positioning of some vital components of the system (filters, fertilizer injector, and emitters).

3) Area of land under cultivation.

4) Skills of the operators, availability of labour, and operational cost.

5) Cost of maintenance.

It is often difficult to have a common practice even if the first two points are harmonized because the underlying factors that influence proper and efficient maintenance could not be far-fetched from the first three points.

2. Materials and Research Methodology

2.1. Description of Study Location

This research was carried out at the soil and water laboratory of the Department of Agricultural & Biosystems Engineering, Landmark University, Omu-Aran, Kwara State, Nigeria. This location lies on latitude 8˚14'02''N, longitude 5˚09'63''E, and altitude 564 m above mean sea level. This location was chosen to investigate a partially controlled environment so as not to compromise the result that would be obtained by the effects of some environmental factors such as rainfall, wind, and temperature. The area of space used is 24 meters square.

2.2. Water Quality Determination

To determine those important parameters that influence the clogging of the emitters, three samples were taken from the drip irrigation systems water source (stream) as done by [6]. Tested parameters were pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), magnesium (Mg), calcium (Ca), Dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD). Analyses of the water were carried out in the laboratory using CONSORT C6020 Electrochemical Analyzer (Plate 2) and JENWAY PFP7 Flame Photometer (Plate 3) as shown below.

Table 1 below shows the results from quality analysis of irrigation water.

Table 1. The results from quality analysis of irrigation water.

Sample	PH	Hazen unit turbidity	US/Cm conductivity	TSS Mg/l	TDS Mg/l	BOD Mg/l	COD Mg/l	DO Mg/l	Ca	Mg
1	6.10	2.00	25.30	20.10	13.61	0.00	0.20	0.10	2.00	0.81
2	6.18	2.00	25.50	35.00	13.50	0.00	0.20	0.10	1.80	0.72
3	6.19	2.00	25.40	38.01	13.62	0.00	0.20	0.10	1.68	0.71
Average	**6.16**	**2.00**	**25.40**	**31.04**	**13.57**	**0.00**	**0.20**	**0.10**	**1.83**	**0.75**

2.3. Materials

Table 2 below shows the materials used for the experiment.

1) Netafim drip irrigation literal (lateral with inbuilt pressure compensating emitters and couplings) with specification below Table 2:

Table 2. The materials used for the experiment.

ID [Internal diameter]	WT [Water throat *i.e.* emitters diameter]	Flow rate
0.46"	0.012"	0.29 GHP
11.8 mm	0.31 mm	1.1L/H @ 1OM height

- 3/4 inch (19 mm) end caps, 3/4 inch (19 mm) elbows, 3/4 inch (19 mm) Netafim control valves.
- Drill machine (Black & Decker) with a set of drill bit., 4 Storage buckets (15 liters capacity).
- Table 2 (2 meters height platform on which water flow from the storage tanks).

- 3/4 inch (19 mm) Netafim threaded joints with clips, Ozone generator, Hacksaw, TOPGIT PVC Gum., Measuring tape, Moringa oleifera roots, Hammer mill, knife and a sterile muslin cloth, Acid (Hydrochloric Acid) Measuring cylinder (200 ml), Collection cups, 1" Angle Iron (3 m in length).

2.4. Procedure and Algorithm

We took the following procedure for measurements of emitter discharge on the lateral is as follows;

Step i. Set up 4 separate installed on a space of 24 meters square. Each set-up has 3 laterals of 1. 6m in length.

Step ii. Mark Drip lines as L1, L2, L3… L12.

Step iii. Mark the position of emitter on each drip lines as A, B C… starting from the emitter point near the sub mainline to the fifth point on the drip line that is E.

Step iv. Mark the point of the collection as L1A, to 1E, and L2A to E and up to L12A to L12E.

Step v. Each set up has a total of 15 emitters on the literal's lines having a cup to collect the discharge from the emitters.

Step vi. Identify the clogged emitters and properly marked before the commencement of testing.

Step vii. Designate each system to be used for water, acid solution (HCL), Ozonized water, and Moringa oleifera root extract solution.

Step viii. Set up new literal lines for water setup to serve as control).

Step ix. Run water through the system on three separate schedules using cleaned water and measure the water discharged from each emitter.

Step x. Separate each setup with acid, ozonized water, and Moringa root extract solution with water for three schedules, discharge and measured at each emitter point on the 4 set up.

Step xi. Operate the entire systems using cleaned water and determine differences in discharges between the first and last irrigation.as shown in plates 3 and 54 of the experimental set-up.

2.5. Aqueous Ozone Generation

To produce aqueous ozone (O_3), a concentration from 1 to 10 ppm of Ozone dissolved in water was generated using GL-3189A Ozone generator made by Origin, Inc. (Princeton, NJ, USA). This generator's feed gas is mainly of ambient air making use of a built-in oxygen concentrator to produce up to 600 mg of Ozone per hour with 7.9% concentration by weight. Ozone was dissolved in water using the generator's venturi injector. The aqueous ozone was then maintained in a recirculation system with a volume of 15 liters, as designed to maintain a constant dissolved Ozone concentration through the adjustment of Ozone generator output based on dissolved oxygen sensor feedback. Maintenance of concentration with a precession of about 0.5 ppm is allowed by this system. Plate 5 was the ozone generator equipment used.

2.6. Procedure and Preparation of Aqueous Solution from Moringa Oleifera Root Extracts

The Moringa oleifera root used in this study were obtained from the Teaching and Research farm moringa oleifera plot of Agricultural Sciences Faculty, Landmark University. The roots were dogged from the ground about 1 m away from each tree stand to avoid any harm. The fresh roots were cut and sliced into pieces and soaked in a stainless-steel pot for three days. 1 litre distilled water was used for the crushing of 10 kg roots. The suspension was stirred using a stirrer for 10 min to extract the active component. The concentrated solution was then filtered through a sterile muslin cloth by squeezing. 0.8 litre of root concentrate was obtained from the process.

The filtered solution was then mixed with 15 litres of water before using it for the removal of biofilms and clogging materials. Plate 7 shows the picture taken after the root was grounded to a past.

2.7. Determination of Active Coagulating Ingredients in Moringa Oleifera Root Extract [Potassium, Sulphate, and Aluminum]

2.7.1. Qualitative Determination of Sulphate and Aluminum

A qualitative analysis of Moringa oleifera root extract solution was conducted to determine the presence of the active coagulating ingredient which is shown below Table 3:

Table 3. Qualitative determination of sulphate and Aluminium.

Test	Observation	Inference
1) Sample solution Diluted $BaCl_{(aq)}$	White precipitate formed	SO_4^{2-} confirmed
2) Sample solution Diluted $H_2SO_{4(aq)}$	Thick white gelatinous precipitate Insoluble in drops but soluble in excess	Al^{3+} confirmed

2.7.2. Quantitative Determination of Potassium, Sulphate, and Aluminum from Moringa Oleifera Root

1) Determination of Potassium ($HNO_3/HClO_4$ digestion method)

A 5 mL of HNO_3 (70%) and 1.5 mL of $HClO_4$ (60%) were added to 0.5 gm of the sample, and the solution heated until the disappearance of the brown fumes. It was then cooled. 5 mL of diluted (1:1) HCl was added and finally diluted with water up to 25 mL solution. The solution was determined by Jenway flame photometer.

2) Determination of Sulphate (Gravimetric method). A 25 mL of the sample was pipetted into a 250 mL beaker. About 50 mL of water and 5 drops of concentrated HCl were added. Heat the mixture to boiling with stirring, a 10 mL of 10% $BaCl_{(aq)}$ dropwise. Cover the beaker with a watch glass and digest for 20 mins. Test

for complete precipitate by adding a few drops of $BaCl_{(aq)}$ to clear the supernatant liquid. The mixture was filtered and washed twice with hot water. Dried and weight until a constant weight is obtained.

3) Determination of Aluminum (Titrimetric method). 25 mL plant sample was pipetted into a 25 mL conical flask. 30 mL 0.01 M EDTA was then added, the resulting solution was boiled for a few minutes to unsure complete complication of the aluminum. The solution is cooled at room temperature, add 1 mL NH_3 solution. Add about 5 - 6 drops of EBT Indicator. 0.01 M $ZnSO_4$ was titrated against the excess EDTA (Table 4).

Table 4. The analytical result showing quantity of potassium, sulphate and Aluminium obtained.

S/N	Potassium (mg/L)	Sulphate (mg/L)	Aluminium (mg/L)
1	15.88	8466	9.145
2	19.75	8302	9.210
3	18.97	8631	8.984

2.8. Evaluation Procedure

For accuracy, we adopt according to [7] [8] and [9] procedure based on measurements of emitter discharges from the literal on the sub-main. Five emitter points on each drip line which is 1.6 m long were tested: The first one is close to the sub-main while the rest are located along the lateral at equal designed spacing.

All the drip lines are marked as L1, L2, L3… L15, emitter location on each (lateral) drip line are marked as A, B, C, D, and E starting from the point near the sub-main line to the 5th point on the drip line that is E. The catch cup was also marked as L1A, L1B… L1E, same for L2A to L2E and up to L12A to L15E. This gives a total of 60 measurement locations as there were 15 emitters in each setup evaluated. The setups under study were divided into four sections and were identified simply as SET1, SET2, SET3, and SET4. SET1 has treatment with acid (HCl), SET2 treatment with Ozonized water, SET3 has treatment with Moringa root extract, and SET4 No treatment (clean water). All Leakages on the main, sub-main, and all the laterals (drip lines) were thoroughly checked and the connections were firmly secured and the evaluated drip system layout plan showing the discharge points' position.

3. System Evaluation and Method of Data Collection

Air bubbles from the lines were removed by first operating the system at operational pressure for some time enough for the line to be cleared of bubbles. This is done before water collection inside sampling the system commences. A container of known size (180 ml) was used for water collection dripping from each emitter. Using a stopwatch, ten minutes was allowed for dispensing water from each emitter and the volume of water collected was recorded. In calculating the flow rate of each dripper, recorded data along the line were used. The recorded rate along the drip lines was then used for analysis. A confidence interval that is acceptable to show that readings were precise as the ones obtained from (Goyal, 2013) was determined.

System Evaluation Parameters

For gravity fed drip system based on the measured data in the study area, the following parameters were used to the evaluation:

1) Emitter average discharge Rate (q_a).

The mean amount of water released by each dripper per unit time is the average emitter discharge rate (q_a). Which is obtained by using

$$q_a = \frac{1}{2}\sum_{i=1}^{n} q_i \tag{1}$$

where:

q_i = flow rate of the emitter i (m^3/s) or (l/h)

n = Total number of emitters.

2) Emitter relative discharge R, can be Calculated with Equation (2)

$$\mathrm{R} = \frac{q_a}{q_n} \tag{2}$$

where:

q_a = mean emitters discharge for each measurement (l/h)

q_n = emitters nominal discharge (l/h)

3) Standard deviation of emitter flow rate (Sq): can be written as:

$$\mathrm{Sq} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(q_1 - q_n\right)^{2s}} \tag{3}$$

where all terms are as described in the above Equations (1)-(3).

4) The Coefficient of Variation of Emitter Flow, Cv

Evaluation of the variability of flow was calculated by dividing the emitter flow rate standard deviation by the mean. The coefficient of variation for each product are usually given by the manufacturers. Cv is expressed as:

$$\mathrm{Cv} = \frac{s_q}{q_a} \tag{4}$$

where:

s_q = emitter flow rate Standard deviation

q_a = average of the emitter discharge rate, l/h

The emitter flow coefficient of variation is found in the table courtesy [10] (Table 5).

Table 5. Classification of coefficient of variation.

Coefficient of variation (Cv)	Classification
>0.4	Unacceptable
0.4 - 0.3	Low

Continued

0.3 - 0.2	Acceptable
0.2 - 0.1	Very good
<0.1	Excellent

Source: Raphael *et al.,* (2018) adapted from ASAE 1997.

6) Statistical Uniformity (Us) used for the evaluation of water application uniformity along the sub-main sections of a drip irrigation system calculated by Equation (5)

$$cv = 100(1 - cv) \quad (5)$$

where: cv = coefficient of variation.

A drip irrigation system uniformity classification was developed to characterize the emitters based on Us and EU (Raphael *et al.* 2018) and presented in **Table 6**.

Table 6. Us and EU comparison.

Classification	Us (%)	EU (%)
Excellent	≥90	94 - 100
Good	80 - 90	81 - 87
Fair	70 - 80	68 - 75
Poor	60 - 70	56 - 62
Unacceptable	<60	<50

Source: Raphael *et al.*, (2018) adapted from ASAE 1997.

7) Emission Uniformity (EU) This was calculated as a function of the relation between the emitted average flow by 25% of the emitters with the lowest flow and the obtained average flow by all emitters, as shown in Equation (6) below.

$$\text{EU} = 100\frac{q_{25\%\ \min}}{q} \quad (6)$$

where:

EU = emission uniformity (%)

$q_{25\%\ \min}$ = average of 25% of the lowest values of flow rate (l/h)

q = average flow rate (l/h)

Following [10] the evaluated system is classified according to the EU values as presented below **Table 7**:

Table 7. System classification according to Emission Uniformity (EU) values.

	Classification	
EU (%)	MERRIAM and KELLER	CAPRA and SCICOLONE
<66	poor	low
66 - 70	poor	mean

Continued

80 - 84	acceptable	
80 - 84	good	
84 - 90	good	high
>90	excellent	

Source: Raphael *et al.*, (2018).

8) Uniformity Coefficient (UC). The uniformity of applying water in drip system of irrigation is evaluated using the uniformity coefficient formula which is represented in ASABE standards:

$$UC = 100\left[1 - \frac{1}{nq_a}\sum_{i=a}^{n}\left(q_i - q_a\right)\right] \quad (7)$$

where:

n = emitters number under consideration

q_a = emitter mean flow rate (l/h)

q_i = Emitter flow rate i (l/h)

Table 8 below shows the classification of Uniformity coefficient.

Table 8. Uniformity coefficient Classification.

Uniformity coefficient, UC (%)	Classification
Above 90	Excellent
80 - 90	Good
70 - 80	Fair
60 - 70	Poor
<60	Unacceptable

Source: (ASABE 2000).

4. Result and Discussion

1) Discharge from Emitters

The discharge from emitters before and after treatment were collected and presented in figures and graphs as shown below.

The discharge of emitters for all setups before and after the treatments were applied is recorded in Tables 5-8. Table 5 shows the discharge recorded before treatment with an acid solution (Hydrochloric acid) and also the discharge of emitters after the treatment was applied and were recorded. Discharges were taking from these emitters three times after the treatment to observe the effect of acid on biofilms causing clogging of the emitters. Table 2 shows the discharge recorded before Aqueous Ozone was applied and also the discharge of emitters when treatment was applied and was recorded. Discharges were taking from these emitters three times after the treatment to observe the effect of Ozone water on biofilms causing clogging of the emitters. Table 7 shows the discharge recorded before treatment with Moringa root extract solution was applied and the discharge of emitters after the treatment was applied and recorded. Discharges were taking from the emitters three times after the treatment to observe the effect of Moringa root extract solution on biofilms causing clogging of the emitters. Table 4 shows the discharge recorded for a setup used as a control without treatment, using clean water. Discharges were taking from these emitters for comparison of distribution efficiency of the systems.

The discharges per treatment are represented in Figures 1-4, while Figure 1 represents the discharges of emitter before and after treatment with an acid solution which is the conventional way of biofilm removal from clogged emitters. Figure 2 represents the discharges of emitter before and after treatment with Aqueous Ozone, Figure 3 represents the discharges of emitter before and after treatment with Moringa Root extract treatment and Figure 4 represents the discharges of the emitter from the control setup without treatment (Table 9).

Table 9. The discharge of emitters for all setups before and after the treatments.

1	Discharge Emitter before & After HCl Treatment														
Emitter Pints	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1**	**12**	**13**	**14**	**15**
Before Trtmt	0.44	040	0.50	0.46	0.32	0.40	0.44	0.26	0.40	0.23	0.40	0.37	0.42	0.40	0.30
1st Trmt	0.54	0.46	0.54	0.51	0.38	0.46	0.54	0.29	0.51	0.45	0.42	0.41	0.41	0.50	0.35
2nd after Trmt	0.64	0.53	0.57	0.52	0.38	0.46	0.55	0.30	0.54	0.45	0.43	0.47	0.43	0.50	0.38
3rd after Trmt	0.56	0.53	0.58	0.52	0.42	0.47	0.56	0.31	0.56	0.47	0.52	0.48	0.44	0.52	0.38
2	**Discharge Emitter before & After Ozone water Treatment**														
Before Trtmt	0.51	0.50	0.48	0.46	0.53	0.54	0.52	0.53	0.55	0.54	0.51	0.51	0.20	0.48	0.52
1st reading after Trmt	0.50	0.51	0.52	0.47	0.54	0.54	0.53	0.55	0.58	0.56	0.55	0.52	0.21	0.53	0.56
2nd Trmt	0.50	0.51	0.52	0.55	0.54	0.54	0.53	0.55	0.58	0.56	0.56	0.53	0.23	0.53	0.56
3rd Trmt	0.54	0.52	0.52	0.56	0.55	0.56	0.54	0.56	0.59	0.57	0.56	0.53	0.24	0.54	0.56
3	**Discharge Emitter before & After Moring root extract solution Treatment**														
Before Trtmt	0.42	0.21	0.44	0.44	0.44	0.35	0.41	0.41	0.43	0.44	0.41	0.44	0.46	0.43	0.41
1st reading after Trmt	0.45	0.21	0.44	0.46	0.44	0.34	0.44	0.44	0.43	0.46	0.42	0.44	0.46	0.44	0.44
2nd Trmt	0.47	0.22	0.48	0.47	0.48	0.35	0.46	0.48	0.43	0.49	0.42	0.44	0.47	0.47	0.44
3rd Trmt	0.47	0.31	0.48	0.48	0.50	0.35	0.47	0.48	0.48	0.49	0.43	0.45	0.47	0.47	0.47
4	**Discharge from Emitter of a new set up with clean water**														
Before Trtmt															
1st Trmt	0.45	0.45	0.44	0.44	0.44	0.34	0.41	0.41	0.43	0.44	0.41	0.44	0.46	0.43	0.41
2nd after Trmt	0.45	0.45	0.44	0.46	0.44	0.34	0.44	0.43	0.46	0.42	0.44	0.42	0.44	0.44	0.44
3rd after Trmt	0.47	0.46	0.48	0.47	0.48	0.35	0.46	0.48	0.43	0.49	0.42	0.44	0.47	0.47	0.44

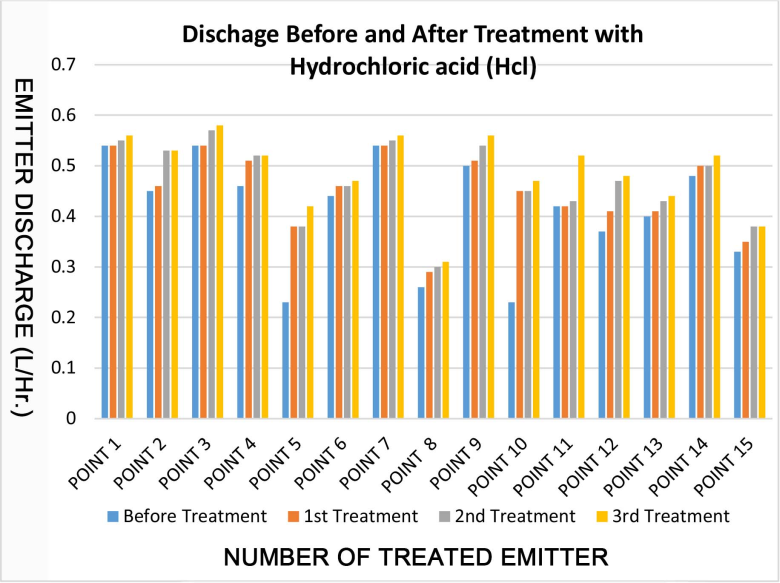

Figure 1. Showing the emitter discharge before and after acid solution treatment.

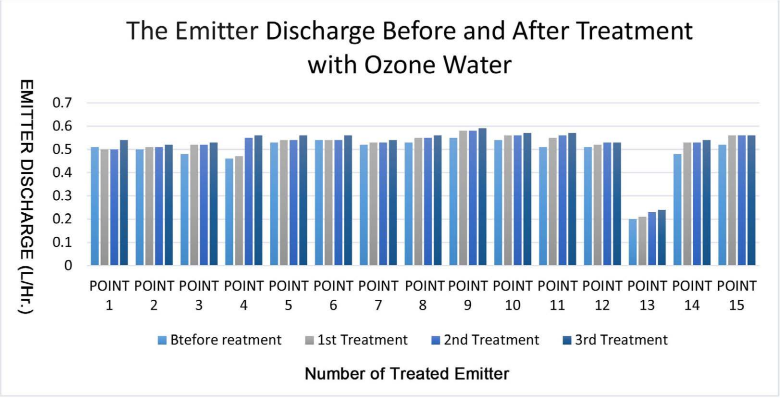

Figure 2. Showing the emitter discharge before and after ozone water treatment.

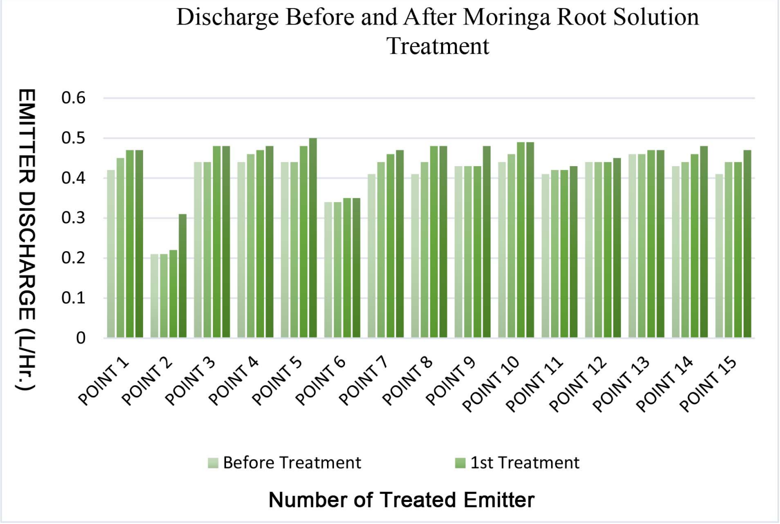

Figure 3. Showing the emitter discharge before and after moringa root solution treatment.

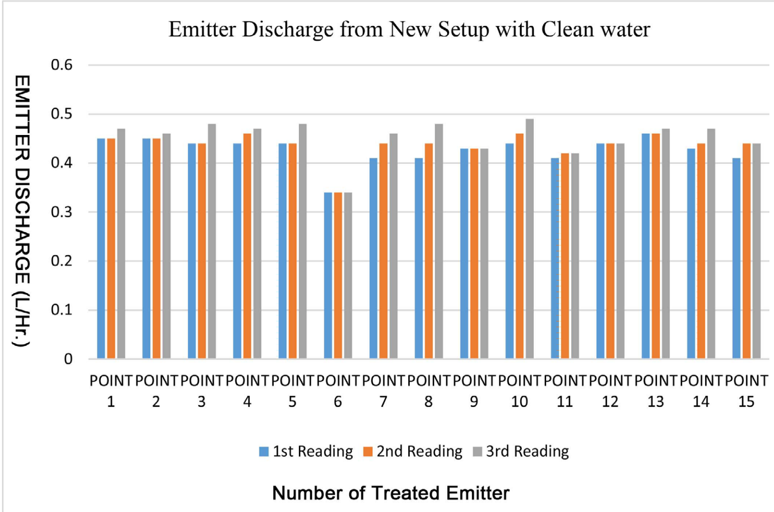

Figure 4. Showing the emitter discharge from a new setup.

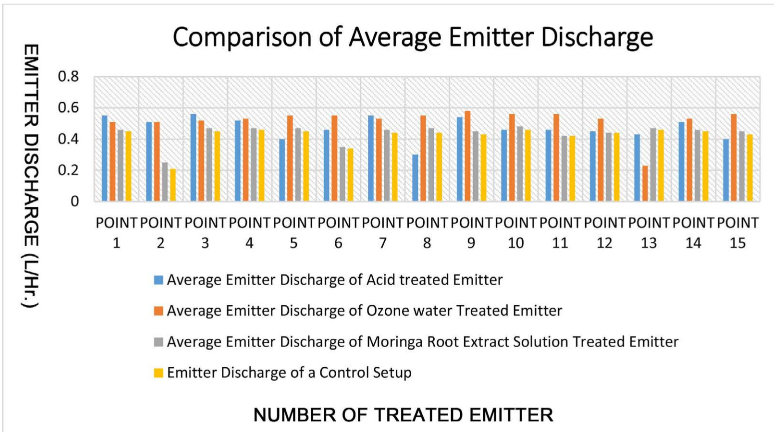

Figure 5. Showing the comparison of average emitter discharge after treatment of a Control Setup.

4.1. Comparison of Average Emitter Discharge after Treatments

From the analysis of the emitter discharge data, the comparison of the average emitter discharge after treatment is represented in Figure 4. Figure 4 and Figure 5 show that Ozone Water treatment has a closer biofilm removal ability with Hydrochloric acid which gives the best performance of biofilm removal and their treated emitters indicated the almost same level of improvement. This is followed by the Moringa Root Extract Solution treatment which indicated a significantly steady performance in removal of biofilm on the emitters (Table 10).

4.2. Comparison of Evaluation Parameters

The evaluation of the data collected from each emitter point of the setup from the various treatments gives values for discharge parameters documented in Table 4, Table 5. Parameters obtained after treatment shows that each treatment has biofilms removal capability because was an increase in the efficiency of the emitter

Table 10. Summary sheet of system performance before and after treatment.

Treatment	R1	R2	R3	Discharge	SE±	R (q_a)	Sq (STDEV)	Cv	Us	Eu	Uc
Before acid treatment	_	_	_	0.38	_	0.345	₦0.08	0.218	78.158	67.01	99.82
Before ozone treatment	_	_	_	0.49	_	0.445	₦0.08	0.173	82.653	83.67	99.53
Before moringa treatment	_	_	_	0.41	_	0.373	₦0.06	0.149	85.122	83.53	100
Acid treatment	0.45	0.47	0.49	0.47	0.011	0.427	₦0.02	0.043	95.745	78.72	100
Ozone water treatment	0.51	0.52	0.53	0.52	0.006	0.473	₦0.01	0.019	98.077	84.64	100
Moringa root treatment	0.42	0.44	0.45	0.437	0.009	0.397	₦0.02	0.035	96.502	84.09	99.24
Control setup	0.41	0.42	O.44	0.415	0.004	0.377	₦0.01	0.017	98.296	83.33	99.21

discharge after application of treatment. From **Table 4**, **Table 5** the evaluation parameter of Emitter average discharge (Qa), Emitter flow rate Standard Deviation (Sq), Emitter Flow Coefficient of Variation (Cv) and Statistical Uniformity (Us) before treatment and after treatment with Hydrochloric Acid were recorded. The Average Emitter discharge (Qa) before treatment was 0.38 l/hr and after the treatment, it increases to 0.47 l/hr. Standard Deviation of emitter flow rate (Sq) of 0.08 before treatment with Hydrochloric Acid and on the application of the treatment it gives 0.02 which is a good indication. Coefficient of Variation of Emitter Flow (Cv) of 0.218 was evaluated before treatment with Hydrochloric Acid and on the application of the treatment, it now gives 0.0425 which is a good indication with excellent performance according to [10]. Statistical Uniformity (Us) of the emitters was 78.16 before the treatment was applied and after Hydrochloric Acid was applied it increases to 95.75. The Emission Uniformity (EU) was 67 before treatment, and this is rated poor going by MERRIAN and KELLER classification but rose close to an acceptable level of 80 that is 78.72 according to Raphael *et al.,* (2018). There was also a slight increase in uniformity Coefficient (Uc) from 99.82 to 100 which is excellent.

The set up for Ozone Water treatment gave an impressive performance. Apart from performing at close range with acid treatment, a steady increase was noted in all the emitters treated. Average Emitter discharge (Qa) before treatment was 0.49 l/hr and after the treatment, it increases to 0.52/hr. Standard Deviation of emitter flow rate (Sq) of 0.08 before treatment with Ozone Water and on the application of the treatment it gives 0.01 which is a good indication. Coefficient of Variation of Emitter Flow (Cv) of 0.17 before treatment with Ozone Water and on the application of the treatment it gives 0.019 which is a good indication with excellence performance according to [10] Statistical Uniformity (Us) of the emitters was 82.65306 before the treatment was applied and after application, it increases to 98.08. Before treatment Emission Uniformity (EU) was 83.67 while Uniformity coefficient (UC) was 99.53. Both had a slight increase of 84.64 and 100 respectively after treatment. Close to Ozone water treatment was Moringa Root Extract Solution treatment. The Average Emitter discharge (Qa) before treatment was 0.41 l/hr and after the treatment, it increases to 0.44 l/hr. Standard Deviation of emitter flow rate (Sq) of 0.06 before treatment with Moringa Root Extract and on the application of the treatment it gives 0.02 which is also a good indication. Coefficient of Variation of Emitter Flow (Cv) of 0.15 before treatment with Moringa Root Extract and on the application of the treatment it gives 0.04 which is also a good indication with excellence performance according to [10].

Statistical Uniformity (Us) of the emitters was 85.12 before the treatment was applied and after Moringa Root Extract was applied it increases to 96.50. Before treatment Emission Uniformity (EU) was 83.53 while Uniformity coefficient (UC) was 100. There was a slight increase in EU to 84.09 while the value of UC dropped to 99.21 after treatment which is still excellent.

4.3. Statistical Inference

The statistical analysis of the treatment is presented in **Table 11**.

Table 11. Statistical analysis of treatment.

Treatment	Discharge	Relative discharge	Cv	Us	EU	Uc
1	0.45	0.41	0.049	95.12	93.33	99.41
1	0.47	0.43	0.047	95.35	89.36	99
1	0.49	0.45	0.044	95.56	85.71	98.61
2	0.51	0.46	0.022	97.83	82.35	98.31
2	0.52	0.47	0.021	97.87	80.76	99.99
2	0.53	0.48	0.020	97.99	79.25	99.97
3	0.42	0.38	0.040	96	100	100
3	0.44	0.4	0.038	96.2	95.45	99.6
3	0.45	0.41	0.038	96.19	93.33	99.4
4	0.41	0.37	0.019	98.08	102.44	100
4	0.42	0.38	0.019	98.13	100	100
4	0.44	0.4	0.018	98.23	95.45	99.6

Key: Acid-1, Ozone water-2, Moringa Root Extract-3, Control Set up-4.

4.4. Result Interpretation

Table 12. ANOVA.

		Sum of squares	df	Mean square	F	Sig.
Emiter discharge	Between groups within groups total	0.017 0.002 0.019	3 8 11	0.006 0.000	23.023	0

Continued

Relative discharge	Between groups within groups total	0.013 0.002 0.015	3 8 11	0.004 0.000	18.575	0.001
Coeff of variation	Between groups within groups total	0.002 0 0.002	3 8 11	0.001 0.000	247.148	0.000
Statistical uniformity	Between groups within groups total	16.686 0.148 16.833	3 8 11	5.562 0.018	301.050	0.000
Emission uniformity	Between groups within groups total	607.04 82.256 689.296	3 8 11	202.347 10.282	19.680	0.000
Uniformity coefficient	Between groups within groups total	1.233 2.473 3.706	3 8 11	0.411 0.309	1.33	0.331

From the output information on the SPSS 23 used, the result for between group of treatment and within group are shown.

The Hypothesis Testing show the following results. The null hypothesis Ho: (μT1 = μT2 = μT3 = μT4).

Alternative hypothesis Ha: (μT1 ≠ μT2 ≠ μT3 ≠ μT4) at $\alpha = 0.05$

Where T = Anti-clogging Chemical treatment.

Levels = T1-Acid Treatment, T2-Ozonized water Treatment, T3-Moringa root extract Treatment, T4-Control.

4.4.1. A Design Guide

In general, if the P-value ("Sig") obtained from an ANOVA test is smaller than the set α value (0.05), the null hypothesis should be rejected and an alternate hypothesis is accepted *i.e.* the difference in the result or mean is significant or otherwise. If the F-value is larger than the f-critical value, that should also lead to the rejection of the null hypothesis. For this study, only the "sig" value or P-value is considered (Table 13).

4.4.2. Emitter Discharge

The result from the ANOVA table shows the P-value to be 0.00 which is less than 0.05. This indicated that for the four treatments to which the clogged drip system was subjected, there was a significant difference in the emitter discharge value after all the four treatments. This leads to the rejection of Ho-that there is no difference in emitter discharge after treatment. However, the highest emitter discharge was obtained after ozonized water was applied. The least improved emitter discharge result was recorded for control of clean water.

Table 13. Summary table for the effect of different anti-clogging treatment of a clogged drip irrigation system used in the study.

Treatment	Discharge mean ± SE	Relative discharge mean ± SE	Coefficient of variation mean ± SE	Statistical uniformity mean ± SE	Emission uniformity (EU) mean ± SE	Uniformity coeffient (UC) mean ± SE
Acid	0.47 ± 0.12	0.43 ± 0.01	0.46 ± 0.01	95.34 ± 0.13	89.47 ± 2.2	99 ± 0.23
Ozonized water	0.52 ± 0.01	0.47 ± 0.01	0.02 ± 0.00	97.89 ± 0.48	80.79 ± 0.89	99.42 ± 0.56
Moringa root extract	0.44 ± 0.01	0.39 ± 0.01	0.03 ± 0.00	96.13 ± 0.06	96.26 ± 1.97	99.67 ± 0.17
Control (clean water)	0.42 ± 0.01	0.38 ± 0.01	0.02 ± 0.00	98.14 ± 0.04	99.30 ± 2.05	99.87 ± 0.13

4.4.3. Relative Discharge

Relative emitter discharge value recorded after treatment was significantly different across all treatments (P = 0.01). Relative discharge is known to be related to actual discharge from the formula for its determination.

4.4.4. The Coefficient of Variation

For the coefficient of variation, the P-value obtained was 0.000 which is less than 0.05. It indicates that the value of the coefficient of variation obtained after treatment was significantly different due to different treatments the clogged drip system was subjected to. Ozonized water treatment has the highest value of Cv classified as "very good" compared to control and acid which is unacceptable.

4.4.5. Statistical Uniformity

The P-value obtained was also 0.00 which is less than 0.05, an indication of a significantly different result.

4.4.6. Emission Uniformity

Here the P = 0.000 indicating significant different result due to different treatments.

4.4.7. Uniformity Coefficient

The obtained P-value was 0.331, which is greater than the set value of 0.05. This shows that Ho Should be accepted and Ha should be rejected. That means there is no significant difference in result due to treatment level (**Table 14**).

Table 14. Summary of the multiple comparisons of the treatment.

1) Average Emitter Discharge						
Treatment	Acid vs ozone	Acid vs moringa root	Acid vs control	Ozone vs moringa	Ozone vs control	Moringa root vs control
P value	0.018	0.113	0.026	0.001	0.000	0.727
Remark	Significant	Not-Significant	Significant	Significant	Significant	Not Significant
2) **Relative emitter discharge**						

Continued

P value	0.054	0.113	0.026	0.002	0.001	0.727
Remark	Significant	Not-Significant	Significant	Significant	Significant	Not Significant
3) The Coefficient of variation						
P value	**0.000**	0.001	0.000	0.000	0.291	0.000
Remarks	Significant	Significant	Significant	Significant	Not Significant	Significant
4) Statistical Uniformity						
P value	0.000	0.000	0.000	0.000	0.189	0.000
Remark	Significant	Significant	Significant	Significant	Not Significant	Significant
5) The Emission uniformity						
P value	0.043	0.118	0.023	0.000	0.000	0.666
Remark	Significant	Not Significant	Significant	Significant	Significant	Not Significant

4.5. Comparison of Emitters' Relative Discharge after Treatment and the Control Setup

The following chart **Figures 6-10** show the Comparison of Emitters' Relative Discharge after Treatment and the Control Setup.

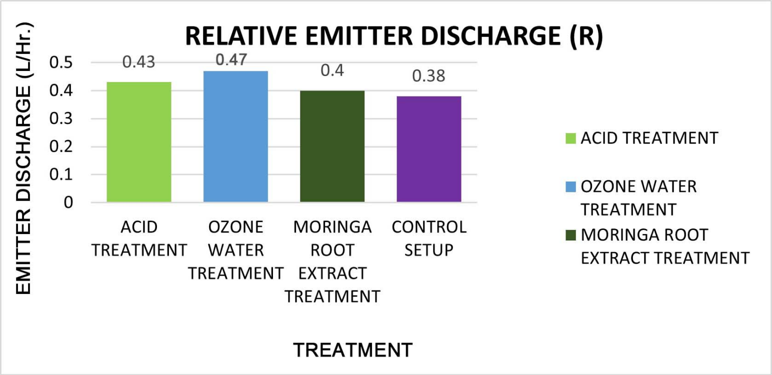

Figure 6. A comparison of emitters' relative discharge after treatment and the control setup.

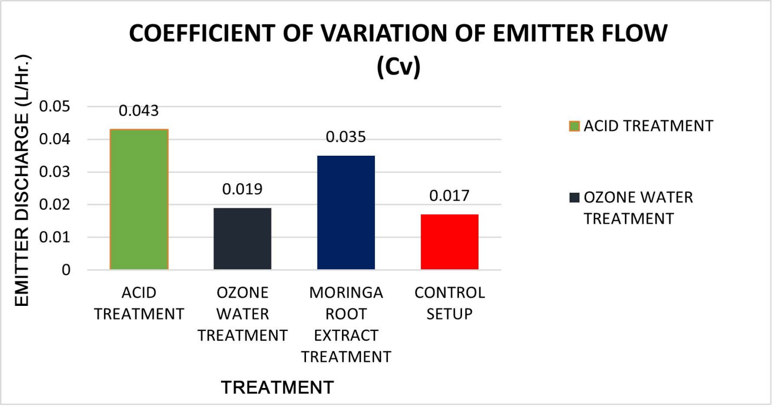

Figure 7. Emitters coefficient of variation after each treatment.

Comparison of Emitter Statistical Uniformity after Each Treatment and the Control setup

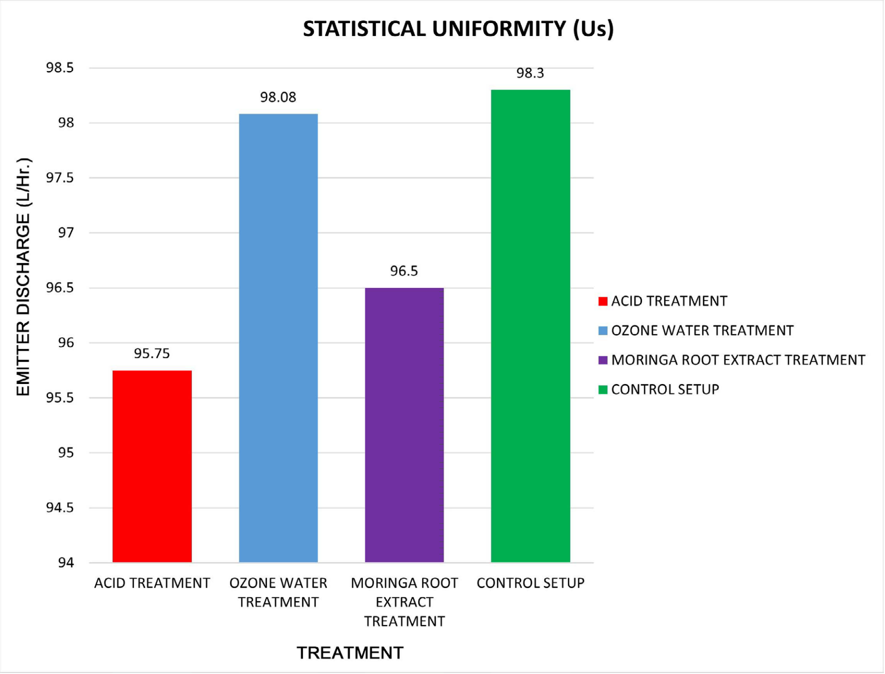

Figure 8. Comparison of emitter statistical uniformity after each treatment and the control setup.

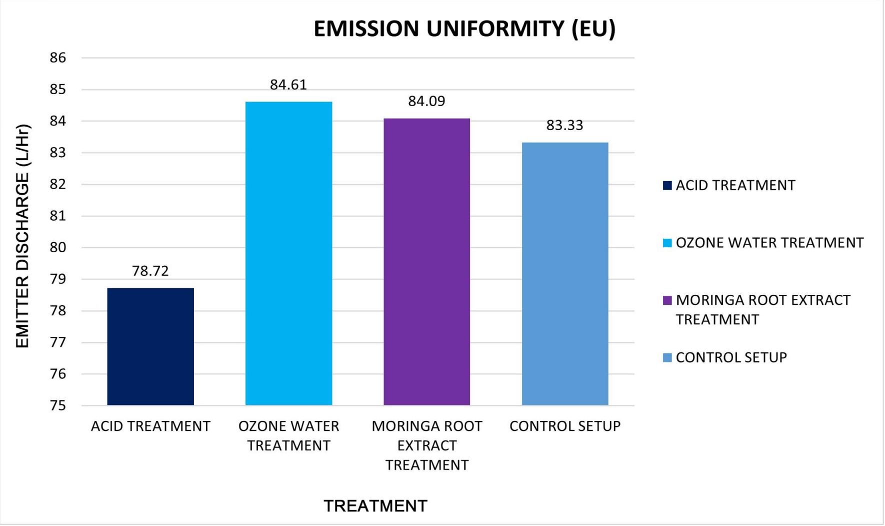

Figure 9. Comparison of emitters' emission uniformity after treatment and the control setup.

5. Conclusions

Based on the investigation and analysis of the data collected from each emitter point of the drip irrigation emitters before and after the application of the treatments, the present paper shows that:

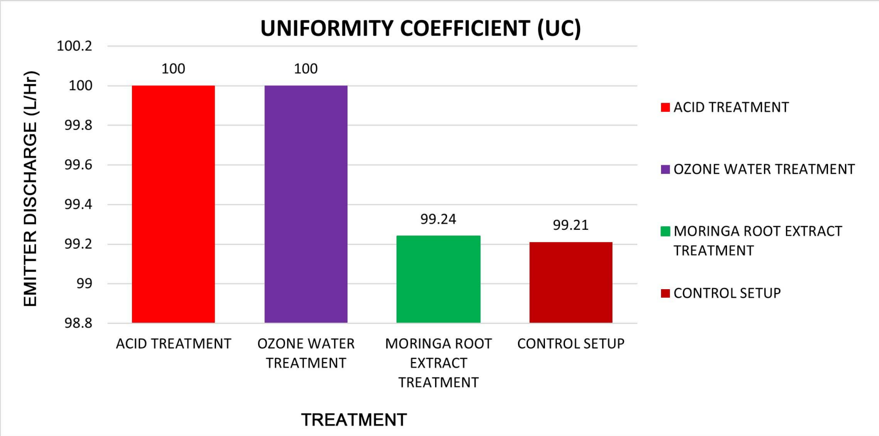

Figure 10. Uniformity coefficient after each treatment compared with the control setup.

1) Hydrochloric acid, Moringa root extract, and Ozone water can be used to remove and inhibit biofilms and their activities. They can also be used in drip irrigation systems as anti-clogging agents for emitters' treatment in agriculture and domestic landscapes.

2) Reduction or complete elimination of the need for repetitive chemical applications for the treatment of clogged emitters can be achieved by using natural means for the removal of biofilms in drip irrigation systems.

3) These solutions may have the potential of controlling pathogenic microorganisms that cause diseases biologically in plants watered with drip irrigation systems not only for the cleaning of clogged emitters.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix 1

```
GET
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DATASET NAME DataSet3 WINDOW=FRONT.
ONEWAY Discharge RelDischarge Cv Us Eu Uc BY Treatments
  /STATISTICS DESCRIPTIVES
  /PLOT MEANS
  /MISSING ANALYSIS
  /POSTHOC=TUKEY DUNCAN ALPHA(0.05).
```

One way

Notes

Output Created		14-OCT-2020 11:02:30
Comments		
Input	Data	C:\Users\Engr Ralph\Desktop\Akande Anti clogging statistics.sav
	Active Dataset	DataSet3
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	12
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on cases with no missing data for any variable in the analysis.
Syntax		ONEWAY Discharge RelDischarge Cv Us Eu Uc BY Treatments /STATISTICS DESCRIPTIVES /PLOT MEANS /MISSING ANALYSIS /POSTHOC=TUKEY DUNCAN ALPHA(0.05).
Resources	Processor Time	00:00:13.73
	Elapsed Time	00:00:15.04

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Emitter Discharge	Acid	3	.4700	.02000	.01155	.4203	.5197	.45	.49
	ozonized water	3	.5200	.01000	.00577	.4952	.5448	.51	.53
	Moringa root	3	.4367	.01528	.00882	.3987	.4746	.42	.45
	control	3	.4233	.01528	.00882	.3854	.4613	.41	.44
	Total	12	.4625	.04115	.01188	.4364	.4886	.41	.53
Relative Discharge	Acid	3	.4300	.02000	.01155	.3803	.4797	.41	.45
	ozonized water	3	.4700	.01000	.00577	.4452	.4948	.46	.48
	Moringa root	3	.3967	.01528	.00882	.3587	.4346	.38	.41
	control	3	.3833	.01528	.00882	.3454	.4213	.37	.40
	Total	12	.4200	.03742	.01080	.3962	.4438	.37	.48
Coeff of variation	Acid	3	.0467	.00252	.00145	.0404	.0529	.04	.05
	ozonized water	3	.0210	.00100	.00058	.0185	.0235	.02	.02
	Moringa root	3	.0387	.00115	.00067	.0358	.0415	.04	.04
	control	3	.0187	.00058	.00033	.0172	.0201	.02	.02
	Total	12	.0313	.01238	.00357	.0234	.0391	.02	.05
statistical uniformity	Acid	3	95.3433	.22008	.12706	94.7966	95.8900	95.12	95.56
	ozonized water	3	97.8967	.08327	.04807	97.6898	98.1035	97.83	97.99
	Moringa root	3	96.1300	.11269	.06506	95.8501	96.4099	96.00	96.20
	control	3	98.1467	.07638	.04410	97.9569	98.3364	98.08	98.23
	Total	12	96.8792	1.23706	.35711	96.0932	97.6652	95.12	98.23
Emission uniformity	Acid	3	89.4667	3.81112	2.20035	79.9993	98.9340	85.71	93.33
	ozonized water	3	80.7867	1.55017	.89499	76.9358	84.6375	79.25	82.35
	Moringa root	3	96.2600	3.40798	1.96760	87.7941	104.7259	93.33	100.00
	control	3	99.2967	3.54768	2.04825	90.4837	108.1096	95.45	102.44
	Total	12	91.4525	7.91601	2.28516	86.4229	96.4821	79.25	102.44
Uniformity coefficient	Acid	3	99.0067	.40004	.23096	98.0129	100.0004	98.61	99.41
	ozonized water	3	99.4233	.96423	.55670	97.0281	101.8186	98.31	99.99
	Moringa root	3	99.6667	.30551	.17638	98.9078	100.4256	99.40	100.00
	control	3	99.8667	.23094	.13333	99.2930	100.4404	99.60	100.00
	Total	12	99.4908	.58046	.16756	99.1220	99.8596	98.31	100.00

Multiple Comparisons

Dependent Variable		(I) Anti clogging	(J) Anti clogging	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Emitter Discharge	Tukey HSD	Acid	ozonized water	-.05000*	.01269	.018	-.0906	-.0094
			Moringa root	.03333	.01269	.113	-.0073	.0740
			control	.04667*	.01269	.026	.0060	.0873
		ozonized water	Acid	.05000*	.01269	.018	.0094	.0906
			Moringa root	.08333*	.01269	.001	.0427	.1240
			control	.09667*	.01269	.000	.0560	.1373
		Moringa root	Acid	-.03333	.01269	.113	-.0740	.0073
			ozonized water	-.08333*	.01269	.001	-.1240	-.0427
			control	.01333	.01269	.727	-.0273	.0540
		control	Acid	-.04667*	.01269	.026	-.0873	-.0060
			ozonized water	-.09667*	.01269	.000	-.1373	-.0560
			Moringa root	-.01333	.01269	.727	-.0540	.0273
Relative Discharge	Tukey HSD	Acid	ozonized water	-.04000	.01269	.054	-.0806	.0006
			Moringa root	.03333	.01269	.113	-.0073	.0740
			control	.04667*	.01269	.026	.0060	.0873
		ozonized water	Acid	.04000	.01269	.054	-.0006	.0806
			Moringa root	.07333*	.01269	.002	.0327	.1140
			control	.08667*	.01269	.001	.0460	.1273
		Moringa root	Acid	-.03333	.01269	.113	-.0740	.0073
			ozonized water	-.07333*	.01269	.002	-.1140	-.0327
			control	.01333	.01269	.727	-.0273	.0540
		control	Acid	-.04667*	.01269	.026	-.0873	-.0060
			ozonized water	-.08667*	.01269	.001	-.1273	-.0460
			Moringa root	-.01333	.01269	.727	-.0540	.0273
Coeff of variation	Tukey HSD	Acid	ozonized water	.02567*	.00122	.000	.0217	.0296
			Moringa root	.00800*	.00122	.001	.0041	.0119
			control	.02800*	.00122	.000	.0241	.0319
		ozonized water	Acid	-.02567*	.00122	.000	-.0296	-.0217
			Moringa root	-.01767*	.00122	.000	-.0216	-.0137
			control	.00233	.00122	.298	-.0016	.0063
		Moringa root	Acid	-.00800*	.00122	.001	-.0119	-.0041
			ozonized water	.01767*	.00122	.000	.0137	.0216
			control	.02000*	.00122	.000	.0161	.0239
		control	Acid	-.02800*	.00122	.000	-.0319	-.0241
			ozonized water	-.00233	.00122	.298	-.0063	.0016
			Moringa root	-.02000*	.00122	.000	-.0239	-.0161
statistical uniformity	Tukey HSD	Acid	ozonized water	-2.55333*	.11098	.000	-2.9087	-2.1979
			Moringa root	-.78667*	.11098	.000	-1.1421	-.4313
			control	-2.80333*	.11098	.000	-3.1587	-2.4479
		ozonized water	Acid	2.55333*	.11098	.000	2.1979	2.9087
			Moringa root	1.76667*	.11098	.000	1.4113	2.1221
			control	-.25000	.11098	.189	-.6054	.1054
		Moringa root	Acid	.78667*	.11098	.000	.4313	1.1421
			ozonized water	-1.76667*	.11098	.000	-2.1221	-1.4113
			control	-2.01667*	.11098	.000	-2.3721	-1.6613
		control	Acid	2.80333*	.11098	.000	2.4479	3.1587
			ozonized water	.25000	.11098	.189	-.1054	.6054
			Moringa root	2.01667*	.11098	.000	1.6613	2.3721
Emission uniformity	Tukey HSD	Acid	ozonized water	8.68000*	2.61814	.043	.2958	17.0642
			Moringa root	-6.79333	2.61814	.118	-15.1775	1.5909

Multiple Comparisons

Dependent Variable		(I) Anti clogging	(J) Anti clogging	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
		ozonized water	Acid	-8.68000*	2.61814	.043	-17.0642	-.2958
			Moringa root	-15.47333*	2.61814	.002	-23.8575	-7.0891
			control	-18.51000*	2.61814	.000	-26.8942	-10.1258
		Moringa root	Acid	6.79333	2.61814	.118	-1.5909	15.1775
			ozonized water	15.47333*	2.61814	.002	7.0891	23.8575
			control	-3.03667	2.61814	.666	-11.4209	5.3475
		control	Acid	9.83000*	2.61814	.023	1.4458	18.2142
			ozonized water	18.51000*	2.61814	.000	10.1258	26.8942
			Moringa root	3.03667	2.61814	.666	-5.3475	11.4209
Uniformity coefficient	Tukey HSD	Acid	ozonized water	-.41667	.45395	.796	-1.8704	1.0370
			Moringa root	-.66000	.45395	.504	-2.1137	.7937
			control	-.86000	.45395	.302	-2.3137	.5937
		ozonized water	Acid	.41667	.45395	.796	-1.0370	1.8704
			Moringa root	-.24333	.45395	.948	-1.6970	1.2104
			control	-.44333	.45395	.766	-1.8970	1.0104
		Moringa root	Acid	.66000	.45395	.504	-.7937	2.1137
			ozonized water	.24333	.45395	.948	-1.2104	1.6970
			control	-.20000	.45395	.970	-1.6537	1.2537
		control	Acid	.86000	.45395	.302	-.5937	2.3137
			ozonized water	.44333	.45395	.766	-1.0104	1.8970
			Moringa root	.20000	.45395	.970	-1.2537	1.6537

The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Emitter Discharge

	Anti clogging	N	Subset for alpha = 0.05 1	2	3
Tukey HSD[a]	control	3	.4233		
	Moringa root	3	.4367	.4367	
	Acid	3		.4700	
	ozonized water	3			.5200
	Sig.		.727	.113	1.000
Duncan[a]	control	3	.4233		
	Moringa root	3	.4367		
	Acid	3		.4700	
	ozonized water	3			.5200
	Sig.		.324	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Relative Discharge

	Anti clogging	N	Subset for alpha = 0.05 1	2	3
Tukey HSD[a]	control	3	.3833		
	Moringa root	3	.3967	.3967	
	Acid	3		.4300	.4300
	ozonized water	3			.4700
	Sig.		.727	.113	.054
Duncan[a]	control	3	.3833		
	Moringa root	3	.3967		
	Acid	3		.4300	
	ozonized water	3			.4700
	Sig.		.324	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Coeff of variation

	Anti clogging	N	Subset for alpha = 0.05 1	2	3
Tukey HSD[a]	control	3	.0187		
	ozonized water	3	.0210		
	Moringa root	3		.0387	
	Acid	3			.0467
	Sig.		.298	1.000	1.000
Duncan[a]	control	3	.0187		
	ozonized water	3	.0210		
	Moringa root	3		.0387	
	Acid	3			.0467
	Sig.		.093	1.000	1.000

Means for groups in homogeneous subsets are displayed.

statistical uniformity

	Anti clogging	N	Subset for alpha = 0.05 1	2	3
Tukey HSD[a]	Acid	3	95.3433		
	Moringa root	3		96.1300	
	ozonized water	3			97.8967
	control	3			98.1467
	Sig.		1.000	1.000	.189
Duncan[a]	Acid	3	95.3433		
	Moringa root	3		96.1300	
	ozonized water	3			97.8967
	control	3			98.1467
	Sig.		1.000	1.000	.054

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Emission uniformity

	Anti clogging	N	Subset for alpha = 0.05		
			1	2	3
Tukey HSD[a]	ozonized water	3	80.7867		
	Acid	3		89.4667	
	Moringa root	3		96.2600	96.2600
	control	3			99.2967
	Sig.		1.000	.118	.666
Duncan[a]	ozonized water	3	80.7867		
	Acid	3		89.4667	
	Moringa root	3			96.2600
	control	3			99.2967
	Sig.		1.000	1.000	.280

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

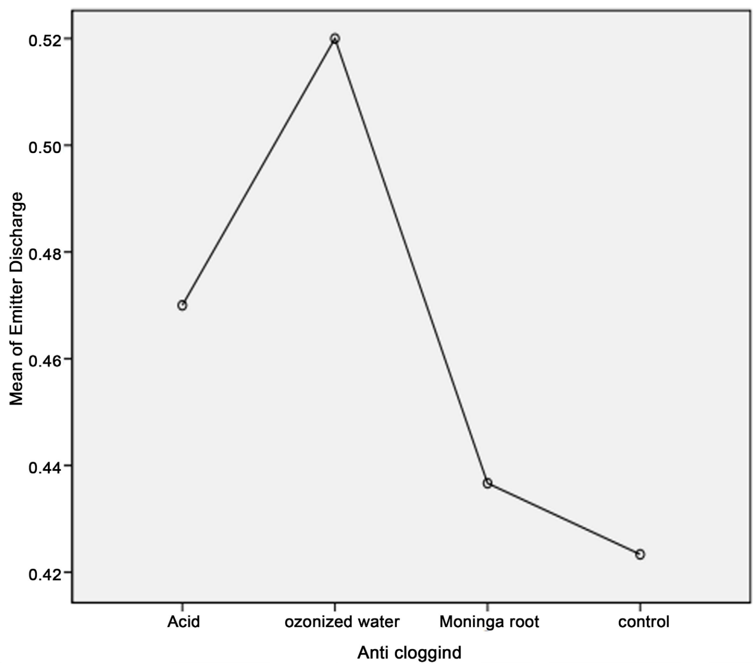
Uniformity coefficient

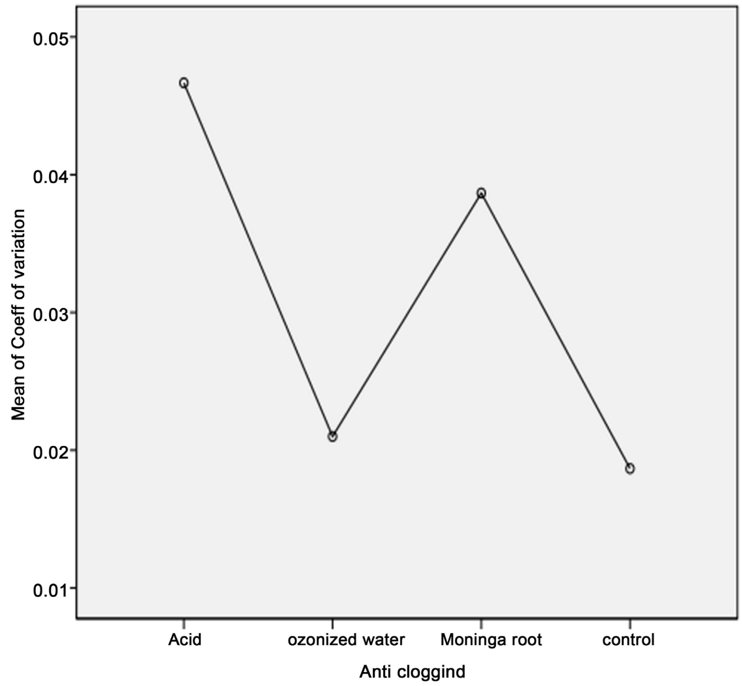
	Anti clogging	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	Acid	3	99.0067
	ozonized water	3	99.4233
	Moringa root	3	99.6667
	control	3	99.8667
	Sig.		.302
Duncan[a]	Acid	3	99.0067
	ozonized water	3	99.4233
	Moringa root	3	99.6667
	control	3	99.8667
	Sig.		.113

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Means Plots

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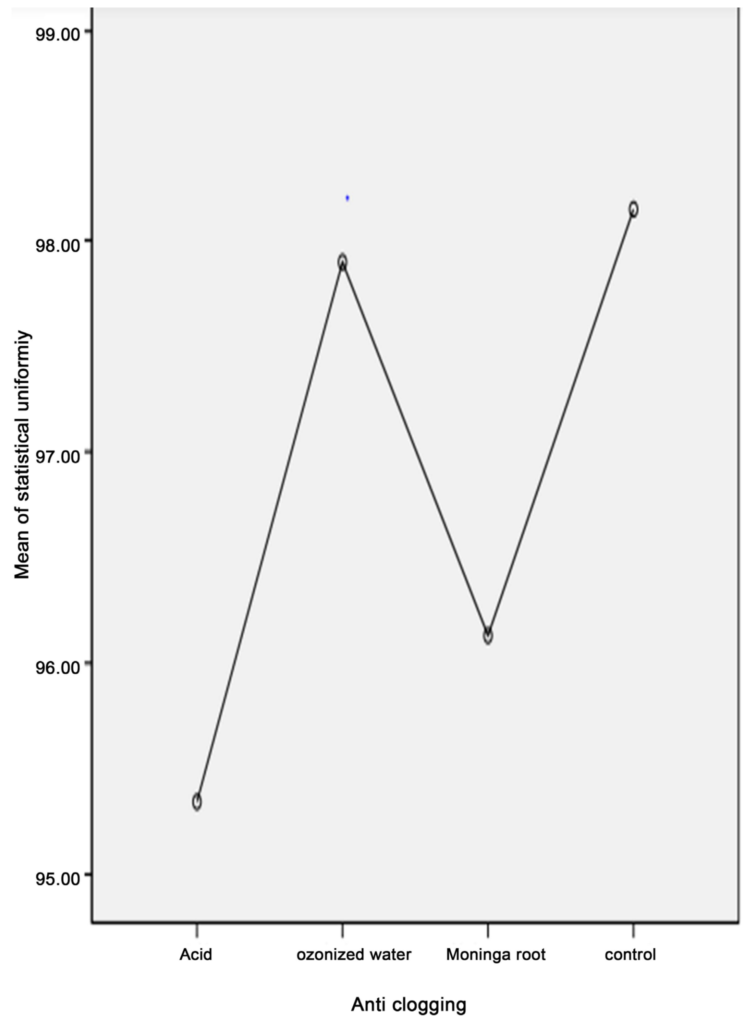
0.04
0.03
0.02
0.01
Mean of Coeff of variation
Acid
ozonized water
Moninga root
control
Anti cloggind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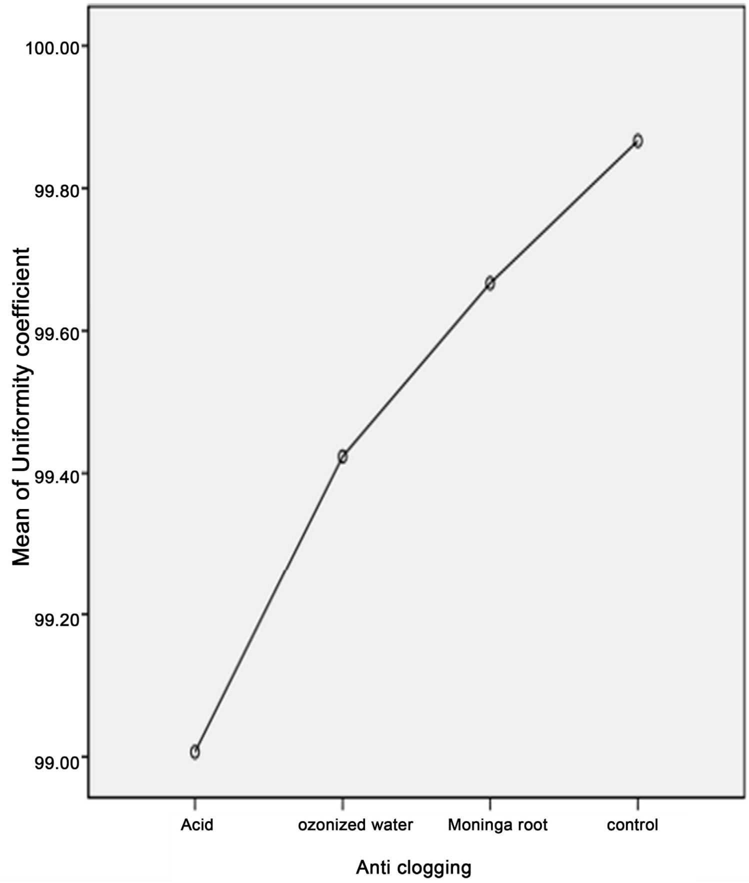
98.00
97.00
96.00
95.00
Mean of statistical uniformiy
Acid
ozonized water
Moninga root
control
Anti clogging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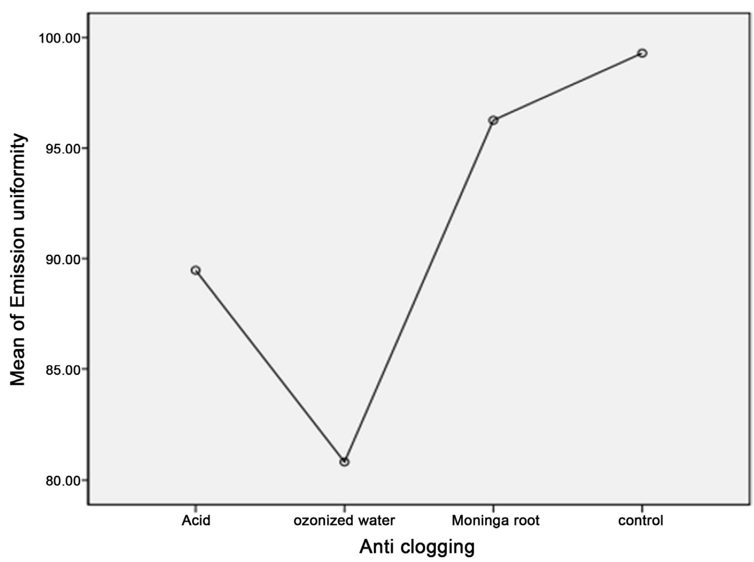
99.20
99.00
Mean of Uniformity coefficient
Acid
ozonized water
Moninga root
control
Anti clogging


100.00
95.00
90.00
85.00
80.00
Mean of Emission uniformity
Acid
ozonized water
Moninga root
control
Anti clogging