Prospects of Sand Filtration and *Moringa oleifera* Seed Solution in Wastewater Treatment for Low-Tech Drip Irrigation

A.Y. Arku*[1], S.M. Musa[2] and L. G. Abubakar[2]

[1]Department of Agricultural and Environmental Resources Engineering, University of Maiduguri, Nigeria.
[2]Department of Agricultural and Bioresource Engineering, Abubakar Tafawa Balewa University, Bauchi, Nigeria.
*adarku2001@yahoo.com; arku@unimaid.edu.ng; +234(0)8020322898

Abstract
Treated wastewater for irrigation is becoming increasingly popular especially in regions of scarce water resources. A 0.15 m diameter model rapid sand filter (MSF) of Polyvinyl Chloride (PVC) with three spouts at 0.20 m, 0.40 m and 0.60 m (from top to bottom) was developed. The single spout filter (SSF) named 'SAMO' filter was redesigned to 0.549 m diameter and 0.853 m long. A 3 x 3 x 5 factorial experiment consisting of three sources of wastewater, three sand filter depths and five concentrations of MSS in three replicates was conducted. Depths were varied at intervals of 0.20 m for testing filter media A[5.50×10^{-4} m], B[7.70×10^{-4} m] and C[1.10×10^{-3} m] from river Ngadda. Mathematical models of the filtration process using Excel package showed discharges of 0.160 m^3/h to 0.06 m^3/h and 0.32 m^3/h to 0.06 m^3/h for the MSF and SSF within the 60-hour run respectively. There is high correlation (R^2=0.90) between filter depth and discharge rate while smaller filter media particle size resulted to lower discharge rates and higher quality of filtered water and vice versa. Field evaluation using the MSF for growing *Amaranthus hybridus* and *Rosa sinensis* showed that 0.20, 0.30 and 0.40 g/L treated wastewaters were good for irrigation at 1.20 L/h emitter discharge and maximum operating pressure of1.68 kN/m^2. Soil quality showed no threats of pollution after irrigation. However, the untreated (control) and 0.10 g/L MSSC-treated wastewaters were not fit for irrigating the crops due to their high coliform levels of 1,400 cells/100 mL. Comparative cost analysis showed that *Moringa oleifera* (MO) is two times cheaper than Alum [$(KAl(SO_4)_2.12H_2O$] and five times cheaper than Hypochlorite (HOCl) for irrigation water treatment. Generally, the filter efficiency was about 70% and further tests were suggested to allow for promotion, patency and commercialization.

Key Words: Sand, Filtration, *Moringa oleifera*, Seed Solution, Wastewater, Treatment

1.0 Introduction

Water is needed in large quantity for a crop or plant to establish and mature. This means the pressure on freshwater is becoming more challenging with growing world population. According to the Johns Hopkins University School of Public Health (1997), it was predicted that by the year 2025 the global population would exceed 9 billion which means more demand for freshwater. The situation is even more alarming especially in arid and semi-arid regions where water is very scarce (UNEP and UN-Habitat, 2010).

Several attempts have been made to explore alternatives to reduce the increasing pressure on freshwater. One of such alternatives is the use of wastewater for irrigation purposes (FAO, 1994). However, use of wastewater poses great health risks to both the farmers and consumers alike due to the presence of disease-causing pathogens if not properly treated. The relatively high discharge rate in rapid sand filtration provides adequate quantity of water required for irrigation agriculture as opposed to slow sand filtration (Ayars *et al.,* 1999). The rapid sand filtration is also important because it removes most suspended particles in the wastewater that could lead to clogging of the system (Polak *et al.,* 1997). The use of rapid sand filters for wastewater treatment though important is not enough in reducing pollutants to a level for irrigation and hence the need for disinfection process specially to remove microbes. The use of plant materials is one of the cheapest methods of wastewater treatment particularly in developing countries. This will in turn, save a lot of foreign exchange.

Many farmers in developing countries utilizing wastewater for irrigation purposes do not treat the wastewater before application on their farms. This could have some health implications on the farmers, the soil and consumers of the crops so produced. Hence, there is the need for wastewater treatment before use. According to FAO (1994), it is recommended that for some agricultural purposes, wastewater from households and municipalities can substitute for freshwater. However, wastewater cannot be used directly unless it is treated so as to minimize its negative effects on the soil, crop irrigated and subsequent consumers of the farm produce. The use of natural materials such as MO has proved to be good alternative to inorganic materials like Alum and Hypochlorite in wastewater treatment. Hence, an attempt was made to explore this option because of its perceived endowments, simplicity and minimum health hazards as an appropriate technology. The use of MO as a wastewater treatment agent has now been established by several researchers (Muyibi, 2006; Sarpong and Richardson, 2010 and Arku *et al*., 2013). This is because it is both a coagulant and antimicrobial, cheap and environmentally-friendly. Hence, the purpose of this research is to investigate the use of rapid sand filtration and *Moringa oleifera* (MO) seed solution in treating wastewater for drip irrigation.

2.0 Experimental Methods

The Study Area and Wastewater Sources

This research was conducted in Maiduguri (Figure 1), the capital of Borno state in north-eastern Nigeria and lies between latitude 11^{o} 51' N and longitude 13^{o} 05' E at an altitude of 354 m above sea level. The city is known for its dryness, with semi-arid climate, light annual rainfall of about 300 mm. Its average daily temperature ranges from 22 – 35 ^{o}C, sometimes with mean of the daily maximum temperature exceeding 40 ^{o}C between March and June before the onset of rains in July to September. It has mainly sandy loam soils. Freshwater is scarce and vegetable farming is practiced by the locals in most parts of the city where wastewaters are discharged.

Fig. 1: Map of Nigeria showing the location of Maiduguri and Wastewater sources

The wastewaters used for the experiments were each collected in one liter bottles from the University Hostel (W_1), Main Abattoir (W_2) and the Nigerian Bottling Company, NBC (W_3) all in Maiduguri metropolis for analyses. Hand gloves were used for protecting the body from contact with the wastewater. Design criteria for the filter were based on recommendations of Droste (1997); AWWA and ASCE (1998) and Tomono and Magara (2002). The filtration at 60 hr run, characterization and standardization at 0.00, 0.10, 0.20, 0.30 and 0.40 mg/L as suggested by Doer (2005), and combined effect of filtration and MSS experiments were conducted between January and February in 2009. An experimental drip irrigation system with medi-emitters was designed, constructed and evaluated using wastewater from the three sources (Arku and Musa, 2014). The field experiments were conducted on the Agricultural and Environmental Resources Engineering Departmental Research Farm between January and February in 2010 and 2011. Summary of Specifications for the Experimental Drip Irrigation System Layout are shown in Table 1.

Table 1: Summary of Specifications for the Experimental Drip Irrigation System Layout

S/No.	Parts of system	Specifications
1	Area coverage	47.50 m^2
2	Type of main	1.80 x10^{-4} m PVC pipe
3	Type of emitter	Medi emitter (5.00x10^{-4} m diameter)
4	No. of emitters	130
5	Emitter spacing	0.50 m for Amaranthus and 1 m for Hibiscus
6	Type of lateral	1.20x10^{-2} m PVC Pipes
7	Lateral length	2.50 m
8	Lateral spacing	1.50 m
9	Type of sub-main	1.20x10^{-4} m PVC pipe
10	Filters	1.0 x10^{-4} m stainless metallic screen and sand ϕ 5.50 x10^{-4} m
11	Filter depths	0.20 m, 0.40 m and 0.60 m
12	System operating head	1 m
13	Water storage	500 L (0.500 m^3) per wastewater sample
14	Crops	Amaranthus and Hibiscus
15	Emitter discharge rate	0.83 L/h max. (Amaranthus), 1.20 L/h max. (Hibiscus)
16	Emitter operating Pressure (maximum)	1.68 kN/m^2
17	Power	0.50 kVA pump

Quality analyses of water, MSS and soil using methods adopted by Arku and Musa (2014). In all, sixty-day growth period was used for the trial crops. Determination of produce quality was two-fold. First, it was the determination of coliform count in the produce. This was done by collecting 50 g of the fresh leaves (close to ground level) of each plant in a one litre plastic bottle with distilled water. It was then introduced into a centrifuge (Hettich-Universal Model 320) at 900 rpm for 10 minutes to remove available coliforms. Each sample was then subjected to the MPN method and coliform counts measured. The second method was determination of various chemical quality parameters in the produce. This was done by sundrying the leaves and preparing into powdered form using local milling machine. Methods used for analyzing the produce quality were as shown by Muyibi (2016).

3.0 Results and Discussion

Quality of filtered wastewaters increased with decrease in media sizes and maximum filter efficiency was about 70%. Hence, the smaller the medium size the better the quality and vice-versa. However, the quality filtered wastewater was not fit for irrigation. Combined effects of the rapid sand filter and MO on domestic (W1), abattoir (W2) and industrial (W3) wastewaters were found to give higher quality of water than the filtration. The wastewaters were treated before irrigating *Amaranthus hybridus* and *Rosa sinensis* on an area of 47.5 m^2. Higher wastewater treatment efficiencies were achieved with MSS when compared with the rapid sand filter performance. MSSC used was directly proportional to the turbidity and coliform count levels of the wastewaters treated (Arku, 2016).

Clogging of emitters was minimally experienced and therefore no need for anti-clogging additive such hydrogen peroxide. The disinfecting action of MO seed did not allow for the accumulation of algae and bacteria at the lateral node. Maximum emitter application efficiency of 98 % was achieved for the 4-h daily irrigation time considered. The treated wastewaters used in the irrigation did not have any adverse effect on the soil properties (Arku and Musa, 2014).

Comparative cost analysis showed that MO was cheaper when compared to Alum and Hypochlorite (Arku *et al.,* 2016) as a disinfectant to treat wastewater for irrigation. Field evaluation using the MSF for growing *Amaranthus hybridus* and *Rosa sinensis* showed that 0.20, 0.30 and 0.40 g/L treated wastewaters were good for irrigation at 1.20 L/h emitter discharge and maximum operating pressure of 1.68 kN/m^2. However, the untreated (control) and 0.10 g/L MSSC-treated wastewaters were not fit for irrigating the crops due to their high coliform levels of 1,400 cells/100 mL when compared to FAO (1994) standards.

4.0 Conclusion

A filter was developed for use in drip irrigation otherwise referred to as 'SAMO' filter. It involves a combination of rapid sand and MSS. It has been found not to pose any health threat to the plants irrigated or humans when used in treating wastewater for drip irrigation. The use of untreated wastewater for irrigation in the study area is therefore not permissible because it has the potential for water-borne and other related diseases.

The backwashing operation for the 'SAMO' filter is difficult due to the short filtration run cycle adopted and also oil present in the MO seed was not extracted. The windy nature of the study area caused displacement of the emission line and therefore sometimes affecting delivery of water directly to the plant root zone needs to be looked into. Patency license can be sought by applying through the appropriate Nigerian government regulatory agency and partnership can be established with the available PVC manufacturers for the production of the different filter components according to desired specifications.

References

Arku, A. Y. (2016). Prospects of Sand Filtration and *Moringa oleifera* Seed Solution in Wastewater Treatment for Low-Tech Drip Irrigation. PhD Thesis submitted to Abubakar Tafawa University, Bauchi, Nigeria.

Arku, A. Y., Musa, S. M. and Abubakar, L. G. (2016). Comparative studies of wastewater treatment using *Moringa oleifera*, hypochlorite and alum for irrigation. *Annals of Borno* . *26*: 60-66.

Arku, A. Y., Musa, S. M. and Ahuchaogu, I. I. (2013). Treatment of wastewater using *Moringa oleifera* in Maiduguri. *Proc. of 34th International conference of the Nigerian Institution of Agricultural Engineers (NIAE) held at Uyo, Akwa Ibom State, Nigeria.*

Arku, A.Y., Musa, S. M and Mofoke, A. L. E. (2012). Determination of water requirement and irrigation timing for *Amaranthus hybridus* in Maiduguri metropolis, north-eastern Nigeria. *Proc. of Fourth International Conference on Sustainable Irrigation organized by Wessex Institute of Technology, UK held at University of South Australia, Adelaide, 10 -14th December, 2012,* 279-289.

Arku, A. Y. and Musa, S. M. (2014). Effect of Moringa-treated wastewater on drip-irrigated sandy loam soil. *Proc. of 12th International conference on Modeling, Monitoring and Management of Water Pollution held at the Algarve, Portugal, 26th – 28th, May, 2014,* 257-268.

AWWA and ASCE (1998). Water Treatment Plant Design. Third Edition. AWWA and ASCE, McGraw-Hill, Inc, New York, NY, Pp 167-180.

Ayars, J. E., Phene, C. J., Hutmacher, R. B., Davis, K. R., Schoneman, R. A., Vail, S. S., and Mead, R. M. (1999). Subsurface drip irrigation of row crops: A review of 15 years of research at the Water Management Research Laboratory. *Agric. Water Manage*., *42*:1-27.

Doer, B. (2005). Moringa Water Treatment (An ECHO Technical Note). Educational Concerns for Hunger Organization (ECHO). *Trees of Life Journal*, ***10** (2):*100-11.

Droste, R. L. (1997). Theory and Practice of Water and Wastewater Treatment. John Wiley & Sons, New York, Pp 416-456.

Muyibi, A. S. (2006). Satiating thirst of millions in Nigeria. Application of processed *Moringa oleifera* seeds in drinking water treatment. *16th Public Lecture delivered at Abubakar Tafawa Balewa University, Bauchi, Nigeria on 3rd August, 2006.*

Food and Agriculture Organization [FAO] (1994). Wastewater treatment and use in agriculture- *FAO irrigation and drainage paper 47*. Pp 26-30.

Polak, P., Nanes, B. and Adhikari, D. (1997). A low cost drip irrigation system for small farmers in developing countries. *J. Am. Water Resources Assoc., 33*: 119-124.

Sarpong, G. and Richardson, C. P. (2010). Coagulation efficiency of *Moringa oleifera* for removal of turbidity and reduction of total coliform as compared to Aluminum Sulphate. *African Journal of Agricultural Research,* ***5** (21)*, 2939-2944.

The Johns Hopkins University School of Public Health (1997). Population Reports. *Winning the Food Race*. Published by the Population Information Program, Center for Communication Programs, Johns Hopkins University School of Public Health, ***25*** (4): 1-7.

Tomono, K. and Magara, Y. (2002). Design of water treatment facilities. Environmental and Health Aspects of Water Treatment and Supply. *Encyclopedia of Life Support Systems.* 209- 280.

UNEP and UN-Habitat. (2010). Sick Water? The central role of wastewater management in sustainable development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. Editted by Corcoran, E., C. Nellemann, E. Baker, R. Bos, D. Osborn, H. Savelli (eds). 2010. Printed by Birkeland Trykkeri AS, Norway, Pp 50- 90.