The Study of the Sewerage Disinfection Properties of Moringa Oleifera Leaf Powder

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Abstract

Apart from its health benefits and coagulant properties, Moringa Oleifera has the possibility to be a sustainable and green alternative to chlorine water disinfection, however, there are limited scientific documented research findings on the disinfection properties of Moringa Oleifera, The objective of this study was to prove that Moringa Oleifera leaf powder has the ability to disinfect sewerage. The Moringa Oleifera used in the study was collected from Kgobokwane village in Mpumalanga province (South Africa). The study was conducted experimentally by dosing a sewerage analogue with Moringa Oleifera leaf powder at 600rpm for one minute, then allowing it and the sludge to settle and the change in Chemical Oxygen Demand (COD) of the samples was then analyzed. A decrease of 40% COD attributed to bacteria was measured and a bone charcoal filter removed 37% of the organic colloids left in the water due to Moringa Oleifera treatment. Based on the pre-mentioned result in traditional water treatment Moringa Oleifera can be implemented to subsidise alum as well as chlorine dosage up to 40% in industrial scale water treatment as a pretreatment with no known negative effects. The limitation of the study is that bacteria was not explicitly tested. In rural areas on a private scale, Moringa Oleifera has the opportunity to pretreat river water before consumption and combined with other technology disinfect household effluent.

Keywords

Moringa Oleifera, Sewerage, Disinfection, COD, Green, Sustainable.

1. Introduction

During disinfection by means of chlorine has the potential byproduct of trihalomethane which may be carcinogenic. By using Moringa Oleifera leaf as a means of disinfection it is possible to negate this, furthermore as Moringa Oleifera is a plant it has the potential to be sustainable (Adejumo et al., 2012). It is commercially sold as spice and tea with natural immune boosting benefits. Moreover, it is sold commercially in additives as pills and energy drinks (Dischem, 2018). The use of Moringa Oleifera by rural communities is unrefined and an empirical trial and error process. This is why a more scientific study and implementation plan is carried out in this study in an effort to standardize and disseminate information about how it can effectively be used.

2. Literature review

Benefits to using Moringa Oleifera as a nutritional supplement the leaf and seed powder is a natural alternative to supplemental pills. Furthermore, Moringa Oleifera is almost fifty per cent fibre, over twenty per cent protein (with all the needed amino acids) and very low in calorific value (Gopalakrishnan et al. 2016; Oyeyinka & Oyeyinka, 2016). Moringa Oleifera has been shown to be beneficial as poultry feed in terms of economics as well as overall poultry health (Paguia et al. 2014). Lastly, Moringa Oleifera has been found to be a terrific source of antioxidants (Conde et al. 2013; Jayawardana et al. 2015). Apart from the nutrients include blood sugar control, cancer control and prevention, aiding in digestive issues in both humans and animals. Finally, Moringa Oleifera assists in maintaining healthy sperm and sperm count (Gopalakrishnan et al. 2016).

Moringa Oleifera has been observed to cure both Type 1 and Type 2 diabetes in rats using Moringa Oleifera seed oil. Additionally, Moringa Oleifera has been observed to contain natural anti-cancer chemicals which have been proven safe and reliable. This chemical acts as not only a prevention measure to cancer but also slows and in some cases stop cancer growth entirely. Moringa Oleifera has shown properties of being a disinfectant and reduce inflammation when administered (Conde et al. 2013; Gopalakrishnan et al. 2016; Jayawardana et al. 2015). Finally, Moringa Oleifera has been witnessed to aid with numerous other diseases like cerebral ischemia, renal dysfunction, stomach ulcers and HIV/Aids to name but a few (Abdull Razis et al. 2014; Gopalakrishnan et al. 2016).

According to the work done by Muyibi & Evison (1995), Moringa Oleifera seeds can be used to treat hard water, though a higher dosage is required with increasing hardness of the water. Likewise, this softening was found to be independent of pH or alkalinity. Finally, they concluded that Moringa Oleifera has the potential for domestic treatment of hard water. Barrado-Moreno et al. (2016) found that Moringa Oleifera seed extract is also very effective at removing algae regardless of pH using a coagulation setup. de Paula et al. (2014) found that for concrete wastewater alum dosage can be reduced by 20% by using Moringa Oleifera which showed an improved turbidity removal compared to Alum alone. Camacho et al. (2017) and Baptista et al. (2015) found that Moringa Oleifera can be implemented with conventional water treatment processes, or alone depending on the use of the product and the source of the water. Likewise, they found it can be used to reduce inorganic coagulants which have the potential to be fully sustainable. Finally due to the biodegradability of Moringa Oleifera makes it an environmentally friendly option.

Moringa Oleifera contains water-soluble, positively charged proteins that act as an effective coagulant for water and wastewater treatment. Crushed seeds are used traditionally to clarify turbid waters in household treatment level in the Sudan and Kenya, in addition, it is successfully used at the pilot scale and full scale in conventional water treatment works in Malawi and applicable to the contact flocculation-filtration process for relatively low turbidity waters. The press cake remaining after oil extraction is also effective as a coagulant and it has the potential for use as an aid to primary sedimentation of wastewater treatment. The only challenge is that Moringa Oleifera, to be utilised in wastewater treatment, it will have to be cultivated intensively on a mass scale which may be expensive (Folkard & Sutherland, 2001; Ndabigengesere et al. 1995). There is no documented research on the active ingredient that is attributed to its disinfection properties, however, informally it is said to be its proteins labelled as de-toxicants.

Pollard et al. (1995) found that it is possible to produce high grade micro-porous activated carbon using Moringa Oleifera seed husks. This can be utilized in adsorption as well as filtration.
The research findings on the disinfection properties of Moringa Oleifera is severely limited in scientific publications, hence as a result, the literature review is very limited and short.

According to the research done by Sarpong & Richardson (2010) using Moringa Oleifera seed oil and Alum, based on the results shown in Figure 1 & 2, full sludge removal using Moringa is possible but not full disinfection due to the organic nature of Moringa Oleifera and the nature of bacteria using said biological material as food.

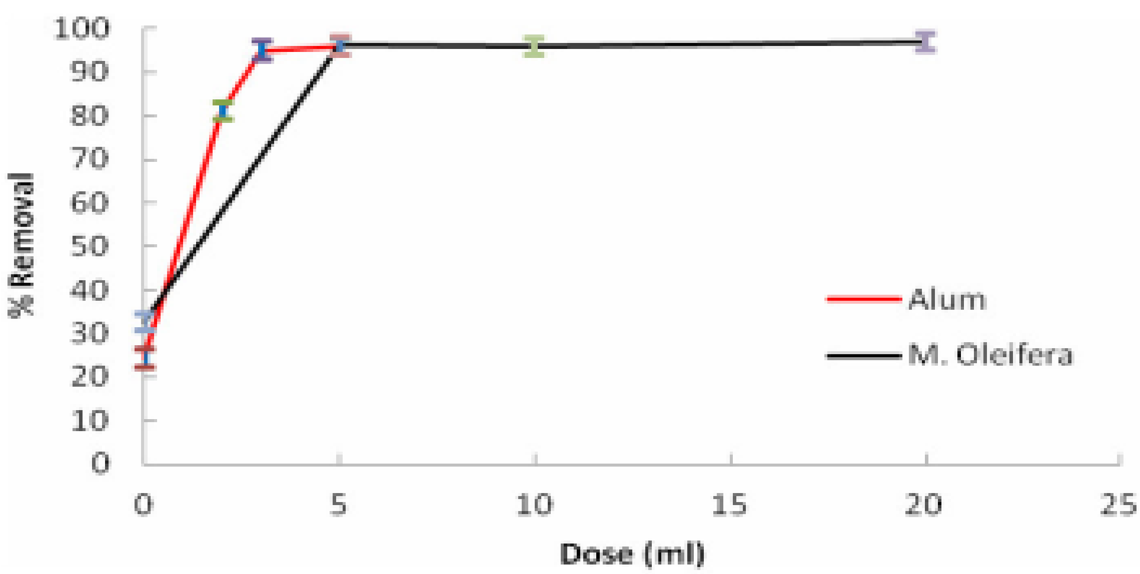

Figure 1: Turbidity Removal vs. Coagulant Dosage (Sarpong & Richardson, 2010).

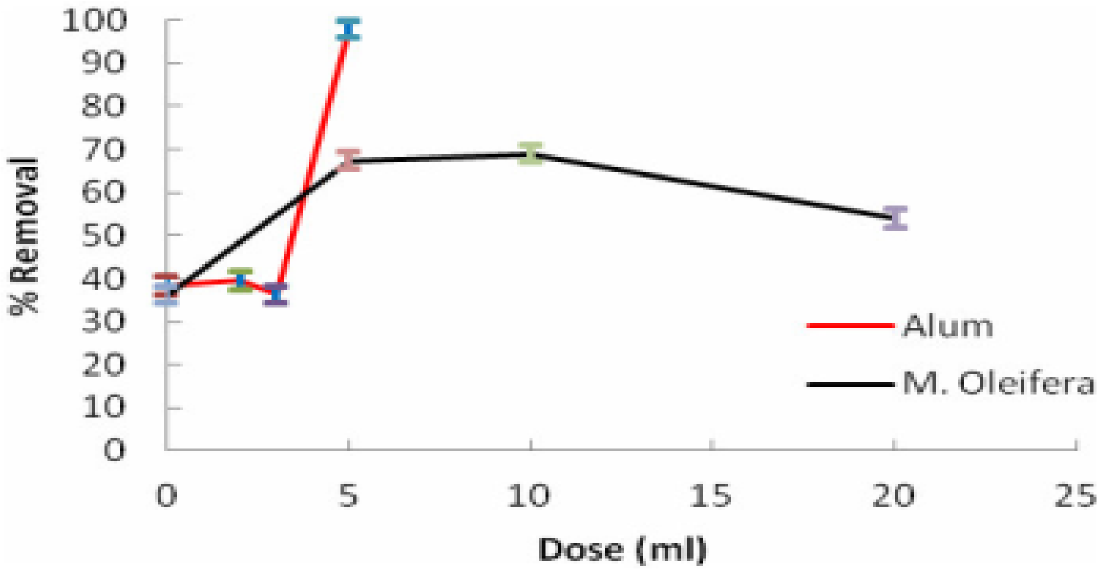

Figure 2: Bacteria Removal vs. Coagulant Dosage (Sarpong & Richardson, 2010).

3. Experimental

3.1. Experimental Set-up

The experimental setup consisted of a Jar test apparatus with four jars with the capacity of one litre. Also, a 30mm packed bed column with a peristaltic pump was used for the bone charcoal (2000 Microns to 5000 Microns) filter. For analysis a vile digester and spectrophotometer (Aqua Lytic AL800) where used. Miscellaneous apparatus used are variously sized beakers, various sized graduated cylinders, various size sieves, a scale, a spatula, a watch glass, a pestle, a mortar, 500ml volumetric flask, glass beads, cotton wool and two five-litre containers.

3.2. Sample Preparation

Moringa Oleifera leaf powder: Moringa Oleifera from Kgobokwane village in Mpumalanga where used. Leaves were selected due to it's the year-round availability. Leaves where washed using water and then ethanol to clean and sterilize, then they dried actively for four hours after which they were dried passively out of direct sunlight in ambient conditions until all moisture was removed. Leaves were then crushed using a pestle and mortar then sieved to be between 500 to 800 microns.
Sewerage Analog: Raw sludge originating from Pretoria supplied by the Daspoort wastewater treatment plant were mixed with deionized water to the ratio of 10% sludge in terms of volume.
COD Catalyst: 250ml of deionized water poured into a 500ml volumetric flask, then 5.108g Potassium Dichromate added and dissolved. 83.5ml of sulphuric acid (98% purity) was then added and the solution was diluted to 500ml.
Bone Charcoal: Bone charcoal was selected due to its availability. Charcoal was roughly crushed and sieved to be between 2000 to 5000 microns. It was then washed using deionized water.

3.3. Experimental Procedure

Disinfection study: 500ml Deionized water for the control and sludge analogue for the study were poured into jars and different dosages of Moringa Oleifera leaf powder were added while stirring at 600rpm. After sufficient mixing (one minute of mixing time), the stirring was stopped and particles allowed to settle for two minutes, then samples were taken. Samples were centrifuged to remove the suspended solids and tested.
Elementary carbon filter: The column was packed with 30g of bone charcoal followed by cotton wool on both sides of the charcoal bed and glass beads to fill the space left. The highest Moringa Oleifera leaf powder dosage control sample of the disinfection study was passed through in a recycle flow configuration to continuously treat the sample.
Testing procedure: 2.5ml of the sample is added into a vile containing 1.5ml COD catalyst mixed with 3.5ml sulphuric acid (98% purity). The vile is capped and placed in the digester at 150°C for 120 minutes after which the vile is

removed and allowed to passively cool. When the vile is cool to the touch the vile was analyzed using the spectrophotometer for COD mid-range with deionized water as the zero.

4. Results and Discussion

4.1. Control

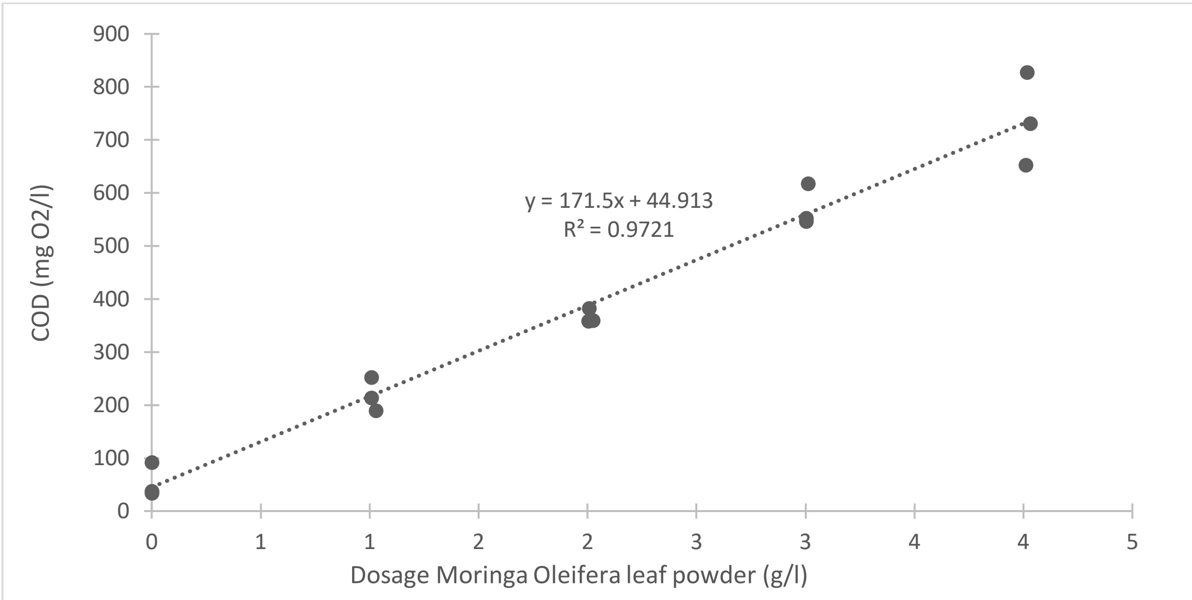

Figure 3: COD change due to Moringa Oleifera leaf powder dosage

Organic colloids from Moringa Oleifera leaf powder were leached by the water in the sample. To determine the change in COD due to bacteria dying the change in COD due to Moringa Oleifera has to be accounted for. Figure 3 is the COD of all the control samples measured against the respective Moringa Oleifera leaf powder dosage. ANOVA single factor analysis of the data grouped as three trials resulted in an F-value of 0.036 and an F-critical-value of 3.885, accompanied with a P-value of 0.965 (see Table 1 in Chapter 4.3). The interpretation of these values yields that the variance between the between the three trials is insignificant. The trend of the data is positive and a linear curve with a regression coefficient (R^2) of 97.21% which yields an equation of $y=171.5x+44.913$, where the 44.913 is the mean COD value of the deionized water. The high regression coefficient combined with the ANOVA single factor results support the use of the correction factor of COD change due to Moringa Oleifera leaf powder dosage is equal to 171.5 multiplied by the dosage in grams and will be used to interpret the results of the disinfection study. The control would be subtracted from the experimental results to intemperate the results in terms of COD denoted by bacteria only.

4.2. Disinfection Study

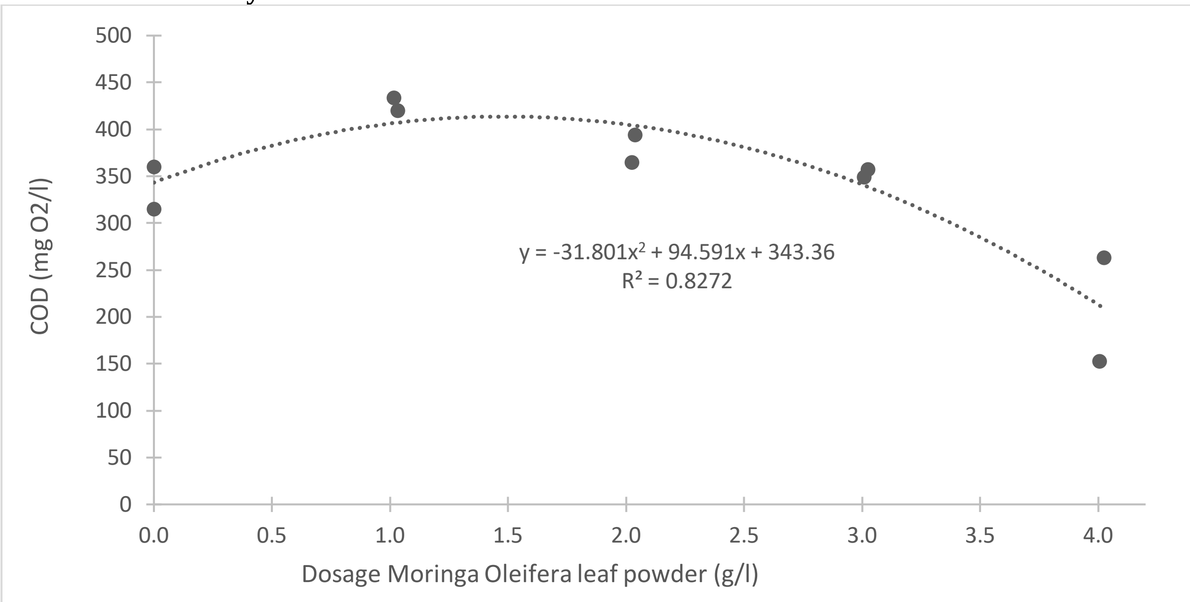

Figure 4: COD as a result of bacteria vs. Moringa Oleifera leaf powder dosage

Figure 4 shows the results after correction of the experimental study testing the disinfection properties of Moringa Oleifera leaf powder on sewerage as COD measured against the respective dosage of Moringa Oleifera leaf powder. ANOVA single factor analysis of the data grouped as three trials resulted in an F-value of 0.009 and an F-critical-value of 3.885, accompanied with a P-value of 0.991 (see Table 2 in Chapter 4.3). The interpretation of these values yields that that variance between the three trials is insignificant. The relationship between COD denoted to bacteria against dosage of Moringa Oleifrea initially increases and the decreases. Multiple runs were conducted to avoid misdirected results and to counteract the effect of human error and on the results. The trend of the data is a negative second order polynomial with the regression coefficient (R^2) of 82.72% and the max residual from the trend being 55mg O2/l. Extending the trend and considering fluctuations in data delivers an optimal dosage between 4.5 to 5.5 g/l. The relatively low regression coefficient indicates that there are fluctuations in the data, furthermore, the ANOVA results indicate that the fluctuations are not impacting the data to the degree that there is a significant variance. Possible reasons for the increase in COD before the decrease is the organic nature of the Moringa Oleifera which could result in an equilibrium case where the organics housing the active ingredients may be feeding the bacteria while the active ingredients reduce the bacteria. A larger dosage was required to have the active ingredients take a larger effect.

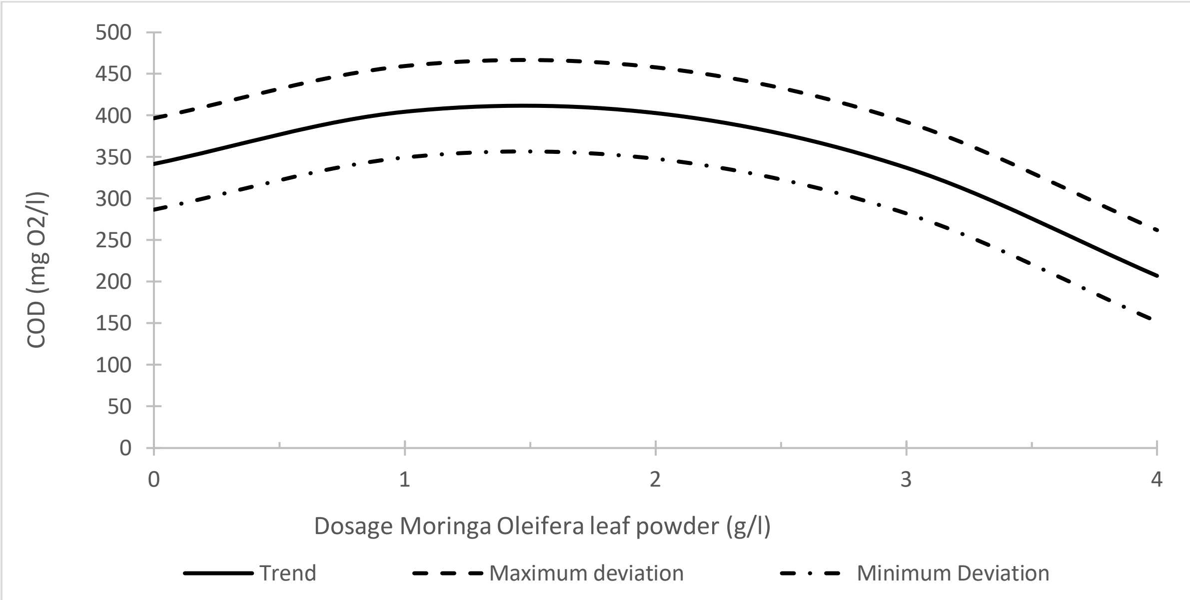

Figure 5: COD as a result of bacteria vs. Moringa Oleifera leaf powder dosage Trend

Figure 5 shows the predicted trend of the COD of the sample after correction with the maximum and minimum deviation to compensate for the fluctuations. The highest measured reduction in COD corresponding to bacteria at a dosage of 4g/l of Moringa Oleifera leaf powder found to be a 40% reduction, this suggests that Moringa Oleifera leaf powder has the capability to disinfect sewerage.

4.3. Removal of organic colloids left by Moringa Oleifera

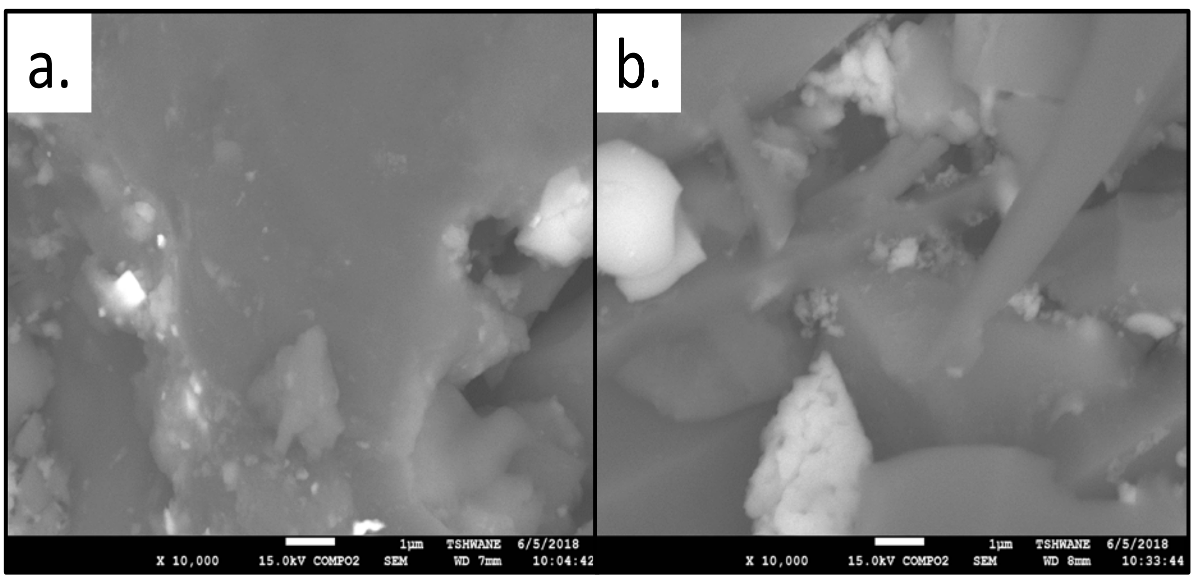

Figure 6: Scanning Electron Microscope (SEM) ×10 000 magnification images of the bone charcoal before (a.) and after (b.) organic colloid adsorption.

Figure 6.a. shows the surface of the bone charcoal before adsorption and Figure 6.b. the surface of the bone charcoal after adsorption using Scanning Electron Microscope (SEM) at ×10 000 magnification. There is a clear precipitation of foreign matter on the surface in comparison (between a. and b.), while there existed foreign matter before (a,) it greatly increased as seen after (b.) as one would expect. There is evidence of microscopic loose carbon particles in both cases which may have contributed to slower mass transfer than expected, additionally the amount of bone charcoal surface covered by the foreign matter is but only a fraction of the available surface, this means that a more

ideal adsorbent will yield greater rates of mass transfer and would be more efficient. The bone charcoal's intended use is to counteract the effect Moringa Oleifera has on the overall water COD and to prove that the effect is easily reversible in conventional water treatment. X-ray Diffraction (XRD) analysis was also done and supported the SEM results. The elementary carbon filter removed 37% of the organic colloids in the sample in continuous recycle flow 17hour treatment.

4.3. Statistical Analysis

Table 1: ANOVA single factor analysis of control trials

ANOVA: Single Factor: **Control**

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Trial A	5	1926	385	71357
Trial B	5	2075	415	99708
Trial C	5	1845	369	55941

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5444.133	2	2722.067	0.035974	0.964769	3.885294
Within Groups	908022.8	12	75668.57			
Total	913466.9	14				

Table 2: ANOVA single factor analysis of disinfection study

ANOVA: Single Factor **Disinfection Study**

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Trial A	5	1671.536	334.3072	12838.8
Trial B	5	1711.908	342.3816	3411.993
Trial C	5	1697.28	339.456	11903.55

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	167.1087	2	83.55434	0.008903	0.991143	3.885294
Within Groups	112617.4	12	9384.78			
Total	112784.5	14				

Table 1 and Table 2 show the summery of the ANOVA analysis done on the raw data obtained for the control and study respectively between Trials. Analysis of variance (AN-O-VA) is a tool used to confirm that the data points between the trials differ to an accepted degree (i.e. with the F-Value lower than the F-Crit Value and P-Value bigger than 0.05 the null-hypothesis is accepted). The resulting conclusion is that the three Trials can be used as one single data set. ANOVA would have statistically shown if there was an uncontrolled variable interfering with the results.

5. Conclusions

Highest reduction in COD donated to bacteria was found to be 40%, representing a 40% reduction in bacteria count. An elementary carbon filter resulted in a COD reduction of 37% representing a 37% reduction in the organic colloids left by Moringa Oleifera. Therefore Moringa Oleifera leaf powder has the capability of disinfecting sewerage and the side effect resulting from said treatment can be negated with an elementary carbon filter. This technology has the possibility to be implemented to subsidies alum and chlorine in the industrial sector and be implemented in rural areas on a personal scale. With optimization, this technology has the possibility to be implemented full industrial scale.

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References
Abdull Razis, A. F., Ibrahim, M. D. & Kntayya, S., Health Benefits of Moringa oleifera, *Asain Pacific Journal of Cancer Prevention*, vol. 15, no. 20, pp. 8571-8576, 2014

Adejumo, O. E., Chukwejekwu, C. N., Kolapo, A. L & Olubamiwa, A. O., Chemical Analysis and Investigative Study on Water Disinfecting Properties of Moringa oleifera (Moringaceae) Leaf, *Pharmacologia*, vol. 3, no. 10, pp. 530-534, 2012

Baptista, A. T. A., Coldebella, P. F., Cardines, P.H.F., Gomes, R.G., Vieira, M.F., Bergamasco, R. & Vieira, A.M.S., Coagulation–flocculation process with ultrafiltered saline extract of Moringa oleifera for the treatment of surface water, *Chemical Engineering Journal*, vol. 276, pp. 166-173, 2015

Barrado-Moreno, M.M., Beltran-Heredia, J. & Martín-Gallardo, J., Microalgae removal with Moringa oleifera, *Toxicon*, vol. 110, pp. 68-73, 2016

Camacho, F.P., Sousa, V.S., Bergamasco, R. & Ribau Teixeira, M., The use of Moringa oleifera as a natural coagulant in surface water treatment, *Chemical Engineering Journal*, vol. 313, pp. 226-237, 2017

Conde, E., Moure, A., Domínguez, H. & Parajó, J.C., Separation, Extraction and Concentration Processes in the Food, Beverage and Nutraceutical Industries, Woodhead Publishing, 1st ed., pp. 506-594. 2013

de Paula, H.M., de Oliveira Ilha, M.S. & Andrade, L.S., Concrete plant wastewater treatment process by coagulation combining aluminum sulfate and Moringa oleifera powder, *Journal of Cleaner Production*, vol. 76, pp. 125-130, 2014

Dischem, Superfoods, Available: https://dischem.co.za/category/742/super-foods, 2018, referenced: 2018/05/24

Folkard, G. & Sutherland, J., The use of Moringa oleifera seed as a natural coagulant for water and wastewater treatment. *International Symposium on Technologies Support for the Management of Water Resources*, Available: https://www.moringanews.org/documents/Folkard.doc, pp. 1-7, 2001, referenced: 2018/05/24

Gopalakrishnan, L., Doriya, K. & Kumar, D.S., Moringa oleifera: A review on nutritive importance and its medicinal application, *Food Science and Human Wellness*, vol. 5, no. 2, pp. 49-56, 2016

Jayawardana, B.C., Liyanage, R., Lalantha, N., Iddamalgoda, S. & Weththasinghe, P., Antioxidant and antimicrobial activity of drumstick (Moringa oleifera) leaves in herbal chicken sausages. *LWT - Food Science and Technology*, vol. 64, no. 2, pp. 1204-1208, 2015

Muyibi, S.A., & Evison, L.M., Moringa oleifera seeds for softening hardwater. *Water Research*, vol. 29, no. 4, pp. 1099-1104, 1995

Ndabigengesere, A., Narasiah, K.S. & Talbot, B.G., Active agents and mechanism of coagulation of turbid waters using Moringa oleifera. *Water Research*, vol. 29, no. 2, pp. 703-710, 1995

Oyeyinka, A.T. & Oyeyinka, S.A., Moringa oleifera as a food fortificant: Recent trends and prospects. *Journal of the Saudi Society of Agricultural Sciences*, vol. 17, no. 2, pp. 1-10, 2016

Paguia, H.M., Paguia, R.Q., Balba, C. & Flores, R.C., Utilization and Evaluation of Moringa Oleifera L. As Poultry Feeds. *APCBEE Procedia*, vol. 8, no. Supplement C, pp. 343-347, 2014

Pollard, S.J.T., Thompson, F.E. & McConnachie, G.L., Microporous carbons from Moringa oleifera husks for water purification in less developed countries. *Water Research*, vol. 29, no. 1, pp. 337-347, 1995

Sarpong, G. & Richardson, C., P., Coagulation efficiency of Moringa oleifera for removal. *African Journal of Agricultural Research*, vol. 5, no. 21, pp. 2939-2944, 2010

Biographies

Douw Gerbrand Faurie is a National Diploma (N-Dip.) in Chemical Engineering 2017 graduate from the Tshwane University of Technology and currently studying his Baccalaureus Technologiae (B-Tech.) in Chemical Engineering, graduating 2018. Douw Faurie completed his Work Integrated Learning (WIL) with the Tshwane University of Technology Chemical Engineering laboratories and is currently volunteering as a mentor for the WIL students as well as doing his industrial project towards his B-Tech. there supervised by Mr M.J. Mosesane. Douw Faurie has a passion for innovation and the advancement of technology with a strong work ethic. The topic of the mentioned industrial project is green energy from waste. Douw Faurie wishes to commence his Masters (Chemical Engineering) in 2019 after completing his B-Tech.

Sthen-Karl Boussougou is currently completing his Work Integrated Learning (WIL) towards his National Diploma (N-Dip.) in Chemical Engineering, graduating 2018, at the Tshwane University of Technology Chemical Engineering laboratories Mentored by Mr D.G. Faurie and supervised by Mr M.J. Mosesane. Sthen-Karl Boussougou has a passion for learning and improvement in himself and his skills with an unrivalled work ethic. He wishes to commence his B-Tech. (Chemical Engineering) in 2019 after completing his Diploma.

Molelekoa James Mosesane holds a Master's Degree in Chemical Engineering and a B-Tech Project Management Degree. He is currently employed by Tshwane University of Technology and studying towards a Master's of Business Administration (MBA). He lectures laboratory classes and design experiments for undergraduates; supervise WIL (P1 and P2), B-Tech and Masters chemical engineering, students. His expertise includes, project management, laboratory management and maintenance, commissioning of pilot plants, liaising with industry, research collaborations and working on different projects for his students.