# Efficacy of Plant Product Extracts for Potable Water Production from Contaminated Water

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## ABSTRACT

Conventional water treatment processes for potable water production in most developing countries are often challenging because of the cost of imported chemicals required for the water treatment coupled with the inherent toxicity associated with chemical disinfection of contaminated water. Hence, the necessity of finding alternative water disinfection technique cannot be understated. This study investigated the potential of using locally sourced plant products, including ginger, garlic, orange, turmeric, aloe vera and red onion; for the treatment of Epe river water and cashew industrial effluent. Microbiological analysis of the treated Epe river water indicated that water samples treated with extracts from orange, aloe vera, ginger, red onions, turmeric and garlic contained estimated number of 2, n, 17, 17, 17, CFU/100 ml coliforms, respectively, when compared with the untreated water sample which had 142 CFU/100 ml coliforms. Chemical analysis of effluent for cashew industrial effluent treated with orange peel as adsorbent, showed that as the dosage and the contact time were increased, the pH, sulphate, biological oxygen demand, chemical oxygen demand, total dissolved solids of the effluents decreased while chloride demand and total suspended solids increased. The study therefore justifies efficacy of plant products for potable water production from contaminated water.

Keywords: plant products, potable water, river water, cashew effluent, bioactive compounds

## INTRODUCTION

Accessibility to safe and affordable drinking water for everyone is one of the 17 sustainable Development Goals to prevent water scarcity and water related diseases. Naturally occurring potable water is not always available as the water is contaminated through human activities and environmental pollution (Fuente *et al.*, 2020; McClelland *et al.*, 2022; Vörösmarty *et al.*, 2010). The demand for water is increasing worldwide due to rapid population growth and industrial growth while the intensity of groundwater and surface water is continuously decreasing due to over development. Potable water is very vital for human survival as consumption of contaminated water can impact human health negatively causing diseases including cholera, dysentery, and typhoid, which can be fatal (Raji and Ibrahim, 2011). Meanwhile, contaminated water can be made potable using various water treatment techniques including physical, chemical and biological treatments.

Nowadays, chemical disinfection of contaminated water is usually carried out using chemicals such as chlorine gas, chlorine dioxide, ozone, chloramines, sodium hypochlorite, calcium hypochlorite and lithium hypochlorite (Gagnon, *et al.*, 2004; Gagnon *et al.*, 2008). However, treatment of water using chemicals such as aluminum sulphate for coagulation and chlorine for disinfection is associated with formation of harmful halogenated disinfection by-products which are carcinogenic (Gang *et al.*, 2002; Nemery *et al.*, 2002; Michaud *et al.*, 2007; Nieuwenhuijsen *et al.*, 2008; Krupinska, 2020; Fouad et al., 2021; Olasupo, 2023;). Besides, chemical treatment of water is expensive, and could have toxic effects on the ecosystem. Hence, it is important to develop alternative water treatment technique, including plant extracts-based water disinfection that can replace chemical treatment technique (Alam *et al.*, 2020; Kurniawan *et al.*, 2020; Varkey, 2020).

For many years, medicinal plants have been used for therapeutic purpose because of the potential of the plants to synthesize metabolites with antimicrobial or disinfection properties that are effective against viruses, bacteria, and fungi (Salma et al., 2013; Bhardwaj et al., 2012; Lawrence et al., 2009). Medicinal plants have also been used for the removal of pollutants including dyes, turbidity, metals, among others (Dohroo et al., 2016; Adugnaet al., 2018; Lee 2015; Bazrafshan et al., 2013; Jinna, 2019; Pallaret al., 2020). Quite a lot of research on useful application of medicinal plants had been conducted but there is limited study on application of medicinal plants for water disinfection to guarantee its commercial application. To overcome the challenge, consideration has been given to the usage of medicinal plants for water disinfection in recent research work. For example, in research conducted in 2022, Alo vera gel was used for the disinfection of water samples from multiple sources including tap water, well water, oil polluted water and leachate (Akinbomi and Ikhide, 2022). Besides, Konkobo et al. (2023) investigated the water coagulation and flocculation effectiveness of some local plant extracts including cactus, Aloe vera sap and Moringa oleifera seeds. Their findings indicated that Moringa oleifera seeds could effectively replace aluminum sulphate as water bio coagulant while *cactus* and *Aloe vera sap*, though less effective as coagulants; could be used as flocculation aids.

To corroborate on the fact that plant extracts are useful as natural water disinfectants, this research investigated potential of using plant extracts for potable water production from contaminated water. The study is important because of the benefits associated with the usage of plant extracts for water treatment which include non-toxicity of the plant extracts, valorization of plant wastes into water coagulant and disinfectant, as well as, the reduced cost of usage of plant extracts as water disinfectants (Shewa and Dagnew, 2020).

## METHODOLOGY

To achieve the research aim, the study was conducted in two stages; the first stage involved using locally sourced plant products, including ginger, garlic, orange, turmeric, aloe vera and red onion; for the treatment of Epe river water and subsequent microbiological analysis of the treated water samples. Appropriate water filter bed configuration was set up followed by hot water extraction of active ingredients of medicinal plants, after which the disinfection of river water samples using the selected medicinal plant extracts, was done. The second stage involved using the most effective plant product in the first stage for the treatment of cashew industrial effluent and subsequent chemical analysis of the treated water samples.

## Preparation of experimental samples

The materials used during the course of the research include sample bottles, autoclave, aluminum foil, gas burner, refrigerator, blender, knife, cheesecloth, pipettes (0.1, 1ml and 10ml), incubator/water bath, test tube stand, media preparation equipment, culture medium, distilled water, plant products, sieve of different mesh sizes, silica gel and weighing balance, among others.

Regarding the first stage of the experiment, the medicinal plant extracts were prepared from garlic, ginger, red onion, orange extract, turmeric and aloe vera gel. The plants were washed, oven dried (at 50°C to ensure the water content was below 10%), peeled and blended into pastes. Hot water extraction process was carried out to extract the plant active ingredients. The boiled mixture was poured into glass flasks, and the flasks put in a shaking incubator overnight at 37 °C and 150 rpm for proper extraction of the plant active ingredients. The resultant slurry was squeezed using a sterile cheese cloth to extract the active ingredients. About 5 g of the extracted juice was dissolved in 95 g of distilled water to obtain 5 % concentration of the plant extract. For the second stage of the experiment, the most effective plant product regarding disinfection of Epe river water during the first stage, was used for the treatment of cashew industrial effluent. Wastewater from industrial processes often contain contaminants that must be removed or reduced to concentration levels that will not have adverse effects on the environment or humans when consumed. Regarding this study, orange peel was obtained as a waste product from Aiyetoro market, Epe, Lagos, Nigeria. The orange peels were washed and sun-dried for two to three days and kept in an oven for 2 hours at 75 °C. The dried orange peels were preserved in a desiccator for 30 mins before they were chopped into smaller pieces. The chopped orange peels were ground using an industrial grinder and the resulting powder form was sieved using two sieves of mesh sizes BSS 10 and BSS 20 to a diameter of 0.85 mm - 2.00 mm. The sieved orange powder was stored in a dry container (air tight) before use.

## **Experimental procedure**

The experimental procedure during the first stage of the study included six steps: preparation and sterilization of sample bottles, collection of water samples, preparation of medicinal

plant extracts (disinfectants), disinfection of river water by mixing with plant extracts, filtration of disinfected river water using filter bed configuration, as well as, microbiological analysis of the disinfected and filtered river water samples. Standard procedures (APHA, 1998; Antony and Renuga, 2012) were followed when carrying out preparation and sterilization of sample bottles prior to their usage for collection of water samples from a river near Epe in Lagos State. The collected water samples were used for the disinfection purpose. For the water disinfection, each plant extract was mixed thoroughly with 500 ml of the river water samples and the mixture was left for an hour before the mixture was poured into the filter bed configuration. The components of the filter bed configuration included 2.36 mm activated carbon, 0.6 mm fine sand, 1.18 mm loamy sand, 4.75 mm coarse sand, filter cloth, and beaker in that order while a retort stand was used to support the filter bed column. The filtered water sample was kept in containers and stored in the refrigerator for not more than 24 hrs. before they were sent for analysis.

The focus of the study during the second stage of the experiment was to evaluate the effectiveness of orange peel sorbent in reducing the concentrations of chemical oxygen demand (COD), biological oxygen demand (BOD<sub>5</sub>), total dissolved solids (TDS), total suspended solids (TSS), Chlorides, Sulphate, as well as, pH level. Pretreatment including washing, drying, and grinding of the sieved orange peel was done to enhance the adsorption capacity and performance. Cashew effluent samples were collected and pretreated using sedimentation method for two hours. The pretreatment would eliminate suspended solids to prevent rapid clogging of the filter column. The cashew effluent was shaken thoroughly and transferred into cylindrical plastic container with a conical bottom (Plate 1).



Plate 1:Cassava effluent treatment setup

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After the water had been allowed to settle for two hours, the suspended solids were drained through an opening in the bottom leaving behind clear pre-treated water. After treatment with the orange peel sorbent, the wastewater was stored in a barrel and cooled to 4 - 6 °C to prevent biological contamination. Characterization of effluent samples before and after treatment with orange peel sorbent was done to determine the pH, COD, BOD<sub>5</sub>, TDS, TSS, Chlorides, and Sulphates constituents of the effluent samples.

## Analysis of experimental samples

Microbiological analysis of raw and treated river water samples was done to ascertain the water disinfection potentials of the medicinal plant extracts. Meanwhile, for the reason that detecting and estimating all potential microorganisms and chemical constituents in water samples might be cumbersome; the scope of the research was limited to the coverage of indicator coliform (*E. Coli*) as indicator for microbial water contamination. *E. coli* is the most important indicator that is often used to indicate faecal contamination in drinking water quality testing. The microbiological analysis of the disinfected water samples was done using the most probable number (MPN) to determine the number of coliform present in the water samples. Regarding chemical analysis, the study coverage included analysis of pH level, sulphate, chlorides, BOD<sub>5</sub>, COD, TDS and TSS concentrations of the water samples.

## FINDINGS

The summary of the results for the microbiological analysis of untreated and treated Epe river water samples for the first stage of the study are given in Tables 1 and 2, respectively. For the second stage of the study, the initial characterization of the raw cashew effluent is shown in Table 3 while the results of the characterization of the treated effluent are presented in Table 4.

Table 1:Results of microbiological analysis of the untreated (raw) Epe river water<br/>samples using the most probable number

Water sample	Sense type	Number of positive tubes	MPN (CFU/100ml)	Lower	upper
Untreated water	5-tubes	532	142	54	405

Table 2:	Results of microbiological analysis of the treated (disinfected) Epe river water
	zsamples using the most probable number

Medicinal plant extract	Sense type	No. of positive tubes	MPN (CFU/100ml)	Lower	Upper
Orange extract	5-tubes	100	2	1	10
Aloe vera	5-tubes	310	11	6	42
Ginger	5-tubes	210	17	6	42
Onion	5-tubes	410	17	6	42

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Medicinal plant extract	Sense type	No. of positive tubes	MPN (CFU/100ml)	Lower	Upper
Turmeric	5-tubes	410	17	6	42
Garlic	5-tubes	410	17	8	44

# Table 3: Raw cashew effluent characteristics

Parameters	BOD	COD	TDS	TSS	рН	Chloride	Sulphate
Characteristics values (mg/l)	2800	4350	9756	156.4	8.3	163.2	3038

# Table 4:Cashew industrial effluent concentration variation with contact time for<br/>various orange peel dosage

	Orange peel dosage (g/L)	Water parameter	Contact time (min)			
			30	75	120	138
1	0.11	pН	8.3	8.2	7.9	7.6
		Chlorides (mg/L)	127	146	155	182
		Sulphate (mg/L)	3037	3025	3014	3002
		BOD (mg/L)	2788	2615	2438	2137
		COD (mg/L)	4323	4201	3984	3890
		TDS (mg/L)	9571	8872	6831	6123
		TSS (mg/L)	159	180	270	341
2	0.30	рН	8.3	7.8	7.1	6.8
		Chlorides (mg/L)	145	179	190	200
		Sulphate (mg/L)	3032	3018	2999	2974
		BOD (mg/L)	2750	2315	2000	1824
		COD (mg/L)	4210	4002	2994	2786
		TDS (mg/L)	9235	7634	5981	4800
		TSS (mg/L)	162	200	460	592
3	0.50	рН	8.2	7.5	6.8	6.4
		Chlorides (mg/L)	158	188	198	230
		Sulphate (mg/L)	3029	3011	2995	2963
		BOD (mg/L)	2335	1478	1009	824
		COD (mg/L)	3247	2285	1840	1416
		TDS (mg/L)	9049	6781	3193	1700
		TSS (mg/L)	170	300	580	694
4	0.75	рН	8.1	7.0	6.5	6.2

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	Orange peel dosage (g/L)	Water parameter		Contact ti	me (min)	
		Chlorides (mg/L)	169	201	226	247
		Sulphate (mg/L)	3025	3004	2947	2913
		BOD (mg/L)	2130	1018	892	720
		COD (mg/L)	3125	1892	1328	1137
		TDS (mg/L)	8967	5904	2873	1280
		TSS (mg/L)	182	450	700	832
5	1.20	рН	7.9	6.8	5.7	5.3
		Chlorides (mg/L)	187	244	290	300
		Sulphate (mg/L)	3019	2982	2901	2884
		BOD (mg/L)	2012	978	408	102
		COD (mg/L)	2987	1781	982	801
		TDS (mg/L)	7692	4568	1893	991
		TSS (mg/L)	215	720	1200	1385
6	1.39	рН	7.6	6.4	5.1	4.9
		Chlorides (mg/L)	191	257	301	327
		Sulphate (mg/L)	3001	2925	2812	2775
		BOD (mg/L)	1986	878	356	85
		COD (mg/L)	2890	1469	891	786
		TDS (mg/L)	7135	3067	1098	824
		TSS (mg/L)	229	800	1320	1460

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## DISCUSSION

For the first stage of the study, the microbiological analysis of Epe river water using most probable number (MPN) indicated that for untreated river water sample (Table 1); five (5) tubes were positive for 10ml sample, three (3) tubes were positive for 1ml sample and two (2) tubes were positive for 0.1ml sample which gives an MPN of one hundred and forty-two (142). Therefore, the water sample contained one hundred and forty-two (142) coliforms per 100ml. For orange extract sample (Table 2); one (1) tube was positive for 10ml sample, none of the tubes was positive for 1ml sample and 0.1ml sample. This gave an MPN of two (2). Therefore, the water sample contained two (2) coliforms per 100ml. For aloe vera water sample (Table 2); three (3) tubes were positive for 10ml sample, one tube was positive for 1ml sample and none of the tubes was positive for 0.1ml sample. Therefore, the water sample contained eleven (11) coliforms per 100ml. For ginger extract water sample (Table 2); two (2) tubes were positive for 10ml sample, one tube was positive for 11ml sample and none of the tubes was positive for 0.1ml sample.

and none of the tubes was positive for 0.1ml sample. Therefore, the water sample contained seventeen (17) coliforms per 100ml. For red onion extract water sample (Table 2); four (4) tubes were positive for 10ml sample, one tube was positive for 11ml sample and none of the tubes was positive for 0.1ml sample. Therefore, the water sample contained seventeen (17) coliforms per 100ml. For turmeric extract water sample (Table 2): four (4) tubes were positive for 10ml sample, one tube was positive for 11ml sample and none of the tubes was positive for 0.1ml sample. Therefore, the water sample contained seventeen (17) coliforms per 100ml. For garlic extract water sample (Table 2); four (4) tubes were positive for 10ml sample, one tube was positive for 11ml sample and none of the tubes was positive for 10ml sample. Therefore, the water sample contained seventeen (17) coliforms per 100ml. For garlic extract water sample (Table 2); four (4) tubes were positive for 10ml sample and none of the tubes was positive for 10ml sample, one tube was positive for 11ml sample and none of the tubes was positive for 0.1ml sample. Therefore, the water sample contained seventeen (17) coliforms per 100ml.

The analysis above reveals that untreated water contained 142 coliforms while water samples treated by orange, Aloe vera, ginger, onion, turmeric and garlic extracts contained two, eleven, seventeen, seventeen, seventeen coliforms, respectively. The results show that plant extracts used as water disinfectants in this study removed large quantity of pathogenic microorganisms from the water samples, which indicates that orange, garlic, ginger, red onion, aloe vera gel and turmeric extracts are reliable water disinfectants. Comparatively, orange extract water sample contained lowest number of coliforms (2 coliforms) per 100ml; Aloe vera gel water sample contained eleven (11) coliforms per 100ml while remaining medicinal plants (ginger, onion, turmeric and garlic) water samples contained seventeen (17) coliforms each per 100ml. Therefore, the results reveal that orange extract is the most effective water disinfectants among others. For the second stage of the study, the results of the chemical analysis of the treated cashew industrial effluent indicates that as the orange peel dosage and contact time were subsequently increased, the concentrations of BOD, COD, TDS, Sulphate, as well as, pH level decreased while concentrations of TSS and Chlorides increased. The results confirm that orange peel is a promising adsorbent for effluent treatment as it can be used to remove a variety of contaminants including heavy metals, dyes, and organic pollutants, among others; from wastewater. The findings in this study are comparable to the findings in previous studies (Alam et al., 2020; Akinbomi et al., 2022).

A number of factors can affect the adsorption of effluent contaminants by orange peel, including pH, contact time, adsorbent dosage and temperature. The optimum pH for contaminant adsorption will vary depending on the specific contaminant being removed. The contact time of the orange peel and the effluent can also affect the adsorption of contaminants. The longer the contact time, the greater the amount of contaminant that will be adsorbed. Regarding adsorbent dosage, the amount of orange peel used (the adsorbent dosage) will also affect the adsorption of contaminants. The higher the adsorbent dosage, the greater the amount of contaminant that will be adsorbed. Effluent temperature of the wastewater can also affect the adsorption of contaminants by orange peel. Generally, the adsorption of contaminants increases with temperature. Meanwhile, the effectiveness of plant product extracts for water treatment could be attributed to the presence of phytochemicals or bioactive compounds in the plant products. Studies have shown that plant products contain bioactive compounds including phenols, quinones, flavonols, tannins, coumarins and alkaloids; which are responsible for plant activities (Adeeyo, *et al.*, 2021). Table 5 shows some bioactive compounds present in the plant product extracts used in this study.

## CONCLUSION

This study investigated the potential for plants products to be used for water decontamination, The study was in two stages; the first stage focused on the microbiological analysis of the raw and treated river water while the second stage focused on the chemical analysis of the raw and treated cashew processing effluent. The experimental variables evaluated during the second stage of the study were time of contact and adsorbent (orange peels) dosage required for reducing the levels of pH, Chlorides, Sulphate, BOD, COD, TDS and TSS present in cashew effluent to the safety levels for human usage. The microbiological analysis indicated that orange extract water sample had, comparatively, the lowest number of coliforms (2 coliforms) per 100ml, signaling that orange extract was the most effective water disinfectant among others. Regarding chemical analysis, application of orange peel extract as a sorbent for the treatment of cashew industrial effluent was effective in the reduction of the BOD, COD, TDS, Sulphate and pH contents of the cashew industrial effluent; as dosage and contact time were increased. Hence, it could be inferred from the experimental results that medicinal plant extracts have some water disinfection efficacies, and that they are promising adsorbents for wastewater treatment. Meanwhile, there are some challenges that need to be addressed in future research work before plant product extracts can be used for commercial applications. Some of the issues to be addressed include inadequate standardization of the plant bioactive compounds, slow rate of bioactive compounds for water coagulation and disinfection, poor solubility of bioactive compounds in water, as well, as the complexity involved in the extraction and purification of the bioactive compounds (Adeeyo, *et al.*, 2021).

	Plant product extracts	Bioactive components
1	Orange peels	Carotenoid, flavonoids, flavones, essential oils and pectin (Sakile, 2023)
2	Aloe vera	Flavonoid, terpenoids, lectins, fatty acids, anthraqunones, mono and polysaccha- rides, tannins, sterols, enzymes, salicyclic acid, minerals and vitamins (Hes <i>et al.</i> , 2019)
3	Ginger	Phenolic compounds (gingerols, shogaols and paradols) and terpene compounds (Mao <i>et al.</i> , 2019)
4	Onion	Sulphur-containing compounds (such as onionin A and Cysteine sulfoxides) and phenolic compounds (such as rutin, quercetin and quercetin glucosides) (Zhao et al., 2021)
5	Turmeric	Curcuminoids (including Curcumin, cyclocurcumin, bisdemethoxy curcumin, and di- methoxy curcumin) and essential oils (Ahmad <i>et al.</i> , 2020)
6	Garlic	Allicin, allin, diallyl sulfide, dially disulfide, diallyl trisulfide, ajoene and s-allyl-cyste- ine (Shaig <i>et al.</i> , 2019)

Table 5:Bioactive compounds in plant products used for the experiment

## **REFERENCES**

- Adeeyo, A.D., Edokpayi, J.N., Alabi, M.A., Msagati, T.A.M. & Odiyo, J.O. (2021). Plant active products and emerging intervention in water potabilization, disinfection and multi-drug-resistant pathogen treatment. *Clinical Phytoscience*, 7, 31.
- Adugna, A.T. & Gebresilasie, N.M. (2018). Aloe steudneri gel as natural flocculant for textile wastewater treatment. *Water Pract. Technol.*, 13: 495–504.
- Ahmad, R.S., Hussain, M.B., Sultan, M.T., Arshad, M.S., Waheed, M., Shariat, M.A., Plygum, S. & Hashempier, M.H. (2020). Biochemistry, safety pharmacological activities, and clinical applications of turmeric: A mechanistic review. *Evid Based Complement Alternat Med.*, 10: 7656019.
- Akinbomi, J.G. & Ikhide, C. (2022). Assessment of disinfection efficacy of sodium hypochlorite and Aloe Vera gel for potable water production from multiple water sources. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, 86: 39-56.
- Alam, M.W., Pandey, P., Khan, F., Souayeh, B. & Farhan, M. (2020). Study to investigate the potential of combined extract of leaves and seeds of moringa oleifera in groundwater purification. *Int. J. Environ Res Public Health*, 17: 7468
- Alazaiza, M.Y. D., Albahnasawi, A., Ali, G.A.M., Bashir, M.J.K., Nassani, D.E. & Al-Maskari, T. (2022). Application of natural coagulants for pharmaceutical removal from water and wastewater: A review. WaterSwitzerl , 14: 140 - 216
- American Public Health Association APHA. (1998). Standards methods for the examination of water and wastewater. 20th edition. Washington DC.
- Andrews, S. (2008). "Disinfectant efficacy in distribution systems: a pilot-scale assessment." *Journal of Water Supply: Research and Technology-Aqua*, 57: 507-518
- Antony, R. M. & Renuga, F. B. (2012). Microbiological analysis of drinking water quality of Ananthanar channel of Kanyakumari district, Tamil Nadu, India. Ambi-Agua, Taubaté, 7 (2): 42-48.
- Bazrafshan, E., Mohammadi, L. & Mostafapour, F.K. (2013). Survey efficiency of coagulation process with poly-aluminum chloride using aloe vera as coagulant aid for arsenic removal from aqueous solutions. *Wulfenia J.*, 20: 323-341.
- Bhardwaj, A., Ballal, S. & Velmurugan, N. (2012). Comparative evaluation of the antimicrobial activity of natural extracts of Moringa citrifolia, papain and aloe vera (all in gel formulation), 2% chlorhexidine gel and calcium hydroxide, against Enterococcus faecalis: An in vitro study. *J Conserv Dent.*, 15: 293-297.
- Dohroo, A., Karnwal, A., and Ghai, M. (2016). Recent developments in Neem (Azadirachtaindica A. Juss) derived antimicrobial constituents for control of human and plant diseases a review. *Ann. Acad. Med. Siles*, 70: 220-223.
- Fouad, M. M., El-Gendy, A. S., Khalil, M.M.H. & Razek, T.M.A. (2021). Aluminum sulfate regeneration from surface water treatment waste in Cairo, Egypt. *Environ. Sci. Pollut. Res.* 28: 61450-61459.
- Fuente, D., Allaire, M., Jeuland, M. & Whittington, D. (2020). Forecasts of mortality and economic losses from poor water and sanitation in sub-Saharan Africa. *PLoS ONE* 15: e0227611-e0227624.
- Gagnon, G.A., O-Leary, K.C., Volk, C.J., Chauret, C., Stover, L. & Andrews, R.C. (2004). Comparative analysis of chlorine dioxide, free chlorine and chloramines on bacterial water quality in model distribution systems. *Journal of Environmental Engineering*, 130: 1269-1279.

#### DOI: 10.5281/zenodo.14776972

- Gagnon, G.A., Baribeau, H., Rutledge, S.O., Dumancic, R., Oehmen, A., Chauret, C., Gaikwad, V. & Munavalli, G. (2019). Turbidity removal by conventional and ballasted coagulation with natural coagulants. *Appl. Water Sci.*, 9:1-9.
- Gang, D., Segar, R.L., Clevenger, T.E. & Banergi, S.K. (2002). Using chlorine demand to predict TTHMs and HAA9 formation, *Journal AWWA*, 94, 10: 76-86.
- Hess, M., Dziedzic, K., Gorecka, D., Jedrusek-Golinska, A. & Gujska, E. (2019). Aloe vera (L) Webb: Natural sources of antioxidants- A Review. *Plant Foods Hum Nutr.*, 74: 255-265.
- Jinna, A., Anu, M., Krishnan, N., Sanal, V., and Das, L. (2019). Comparative study of efficiency of local plants in water treatment. *Int. Res. J. Eng. Technol.*, 6: 4046 4052.
- Katubi, K.M., Amari, A., Harharah, H.N., Eldirderi, M.M., Tahoon, M.A. & Ben Rebah, F. (2021). Aloe vera as promising material for water treatment: A Review. *Processes*, 9, 782.
- Konkobo, F.A., Diao, M., Savadogo, P.W., Diarra, J., and Dicko, M. H. (2021). Comparative study of the effects of herbal and chemical coagulants in the clarification of raw water. *Afr. J. Agric. Res.* 17: 532-541
- Konkobo, F.A., Savadogo, P.W., Diao, M., Dakuyo, R. & Dicko, M. (2023). Evaluation of the effectiveness of some local plant extracts in improving the quality of unsafe water consumed in developing countries. *Front. Environ. Sci.* 11:1134984
- Krupinska, I. (2020). Aluminum drinking water treatment residuals and their toxic impact on human health. *Molecules* 25: 641-713
- Kurniawan, S.B., Abdullah, S. R. S., Imron, M. F., Said, N. S. M., Ismail'zzati, N. & Hasan, H. A. (2020). Challenges and opportunities of bio-coagulant/bio-flocculant application for drinking water and wastewater treatment and its potential for sludge recovery. *Int. J. Environ. Res. Public Health* 17: 9312 – 9333.
- Lawrence, R., Tripathi, P., and Jeyakumar, E. (2009). Isolation, Purification and Evaluation of Antibacterial Agents from Aloe Vera. *Brazilian Journal of Microbiology*, 40: 906-915.
- Lee, K.E., Hanafiah, M.M., Halim, A.A. & Mahmud, M.H. (2015). Primary treatment of dye wastewater using Aloe vera-aided aluminum and magnesium hybrid coagulants. *Procedia Environ. Sci.*, 30: 56–61
- Mao, Q-Q., Xu, X-Y., Ca, S-Y., Gan, R-Y., Corke, H., Beta, T. & Bin, H. (2019). Bioactive compounds and bioactivities of ginger (*Zingiber officinate Rosco*). *Foods*, 8:185
- McClelland, P.H., Kenney, C.T., Palacardo, F., Roberts, N.L.S., Luhende, N. & Chua, J. (2022). Improved water and waste management practices reduce diarrhea risk in children under age five in rural Tanzania: A community-based, cross-sectional analysis. *Int. J. Environ. Res. Public Health* 19: 4218
- Michaud, D.S. M., Kogevinas, K.P., Cantor, C.M., Villanueva, R., Garcia-Closas, A., Tardon, A., Carrato, M., Dosemeci, D., and Silverman, T. (2007). Total fluid and water consumption and the joint effect of exposure to disinfection by-products on risk of bladder cancer. *Environ Health Perspect*, 115: 1569-1572.
- Nemery, B., Hoet, P.H.M. & Nowak, D. (2002). Indoor swimming pools, water chlorination and respiratory health. *European Respiratory Journal*, 19: 790-793.
- Nieuwenhuijsen, M.J., Toledano, M.B., Bennett, J., Best, N., Hambly, P., de-Hoogh, C., Wellesley, D., Boyd, P.A., Abramsky, L., Dattani, N., Fawell, J., Briggs, D., Jarup, L. & Elliott, P. (2008). Chlorination disinfection byproducts and risk of congenital anomalies in England and Wales. *Environmental Health Perspectives*, 116: 216-222

- Olasupo, J. I. (2023). Potential use of plant extract for water purification: A review. *International Journal* of *Research and Review*, 10: 74-79.
- Pallar, B.M., Abram, P.H. & Ningsih, P. (2020). Analysis of hard water coagulation in water sources of Kawatuna using Aloe Vera Plant. *Journal Akademika. Kimia*, 9: 125–132
- Raji, M.I.O. & Ibrahim, Y.K.E. (2011). Prevalence of water-borne infections in North Western Nigeria: a retrospective study. *Journal of Public Health and Epidemiology*., 3: 382-385.
- Sharg, A., Cao, S-Y., Cao, S-Y., Xu, X-Y., Gan, R-Y., Tang, G-Y., Gerke, H., Mavumrngioana, V., Li, H-B. (2019). Bioactive compounds and biological function of garlic (*Allium sativum L*). *Foods*, 8:246.
- Sakile, H., Satish, M.H.S., Kandapal, C., Sanasam, P. & Bajaj, I. (2023). *The Pharma Innovation Journal*, 12: 01-16.
- Salma, K. and Zeeshan, A. (2013). Herbal disinfectants: a review. *World Journal of Pharmaceutical Research*, 3: 258-273.
- Shewa, W. A. & Dagnew, M. (2020). Revisiting chemically enhanced primary treatment of *wastewater*: A review. *Sustain. Switz.* 12: 5928.
- Varkey, A. J. (2020). Purification of river water using Moringa Oleifera seed and copper for point-of-use household application. *Sci. Afr.* 8: e00364 e00368.
- Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., and Prusevich, A. (2010). Global threats to human water security and river biodiversity. *Nature*, 467: 555-561.
- Zhao, X-X., Lin, F-J., Li, H., Li, H-B., Wu, D-T., Geng, F., Ma, W., Wang, Y., Miao, B-H., and Gan, R-Y. (2021). Recent advances in bioactive compounds, health functions, and safety concerns of onion (*Allium Cepa L*). *Front. Nutr.* 8: 669805.