Available: https://doi.org/10.54117/j2qae873 *Research Article*

African Journal of Applied Research & Sustainable Development
4(1): 47-58 (2026)
Received: 27 Dec 2025, Accepted: 23 Jan 2026, Published: 01 Feb 2026

Disinfecting Potentials and Eco-Safety Evaluation of Nano-treated Surface Water Resources by Biogenic Silver Nanoparticles Using Bacterial and Phytotoxicity Indices

Uba, B. O.[1*], Okonkwo, O. P.[1], Idigo, M. A.[2], Igiri, V. C.[3], Okongwu, D. J.[4], Okemadu, O. C.[5] and Anaebonam, E. C.[6]

[1]Department of Microbiology, Chukwuemeka Odumegwu Ojukwu University, P.M.B.02 Uli, Anambra State, Nigeria.
[2]Applied Entomology, Chukwuemeka Odumegwu Ojukwu University, Igbariam Anambra State, Nigeria
[3]Department of Microbiology, University of Agriculture and Environmental Sciences, Umuagwo Imo State, Nigeria.
[4]Department of Chemistry, Nwafor Orizu College of Education University, Nsugbe, Anambra State, Nigeria.
[5]Department of Medical Laboratory Science, Tansian University Oba Campus, Anambra State, Nigeria.
[6]Department of Public Health, Tansian University Oba Anambra State.
*Corresponding author email: bo.uba@coou.edu.ng

Abstract
Nanotreated wastewater safety is assessed via phytotoxicity tests, checking its impact on plants. So, understanding how nanoparticles treated surface water affect plant growth is key to assessing environmental risks to food safety and human health. This study was undertaken to determine the disinfecting potentials and ecological safety evaluation of post - nanotreated surface water resources by biogenic silver nanoparticles using bacterial load and phytotoxicity indices. *M. oleifera* and *C. papaya* aqueous seed extracts were phytochemically analyzed and used to synthesize silver nanoparticles via titration. The nanoparticles were characterized using UV-VIS spectroscopy. Surface water samples (1 L) treated with 5 mg/mL nanoparticles for 30 - 120 min were analyzed for physicochemical and bacterial changes. The phytochemical results revealed that flavonoids, terpenoids and saponins were present in both *M. oleifera* and *C. papaya* aqueous seed extracts. The conversion of colourless silver nitrate to brownish then to dark brown colour after 24 hr confirming the successful synthesis of silver nanoparticles. The UV - Vis spectral revealed that the maximum peak of both AgNPs was at 400 nm each while the minimum peaks were at 800 nm and 700 nm, respectively. It revealed that *M. oleifera* and *C. papaya*-synthesized silver nanoparticles effectively reduced bacteria count in water samples. The nanoparticles' effect increased with contact time (30 - 120 min) showing time dependence ($P < 0.05$). Also, it revealed that the bacterial strains were all Gram negative short rods and classically identified using Bergeys' Manual as *Klebsiella pneumoniae, Enterobacter aerogenes* and *Escherichia coli* as the indigenious possible bacterial pathogens. Moreso, sample A of *C. papaya* treatment had the highest (68.19 %) and sample D of *M. oleifera* treatment had the lowest (29.74 %) germination index in *Zea mays* L. while sample C of $CaOCl_2$ treatment had the highest (45.83 %) and sample E of *C. papaya* treatment had the lowest (6.66 %) germination index in *Phaseolus vulgaris.* Thus, the present study demonstrated the facile synthesis of low cost, moderate ecofriendly and efficient green water purifiers.

Keywords: Disinfection, Environmental monitoring, Nanoagent, Phytotoxicity, Water resources

How to cite: Uba, B. O., Okonkwo, O. P., Idigo, M. A., Igiri, V. C., Okongwu, D. J., Okemadu, O. C., & Anaebonam, E. C. (2026). Disinfecting potentials and eco-safety evaluation of nano-treated surface water resources by biogenic silver nanoparticles using bacterial and phytotoxicity indices. *African Journal of Applied Research & Sustainable Development*, 4(1), 47–58. https://doi.org/10.54117/j2qae873

Introduction
Water pollution is generally a worldwide problem leading to different health issues and the World Health Organization (WHO) has estimated that up to 80 % of all diseases and sickness in the world is caused by inadequate sanitation, polluted water or unavailability of water. In Nigeria, the most common source of drinking water for the rural population is from ponds, wells, rivers, stream, and borehole water. Water from these sources is usually consumed without treatment whatsoever (Megersa *et al.*, 2014). However, 10 % of these diseases could be prevented by improvements related to drinking water, sanitation, hygiene and water resource management (WHO, 2008; Uba *et al.*, 2017; Dokubo *et al.*, 2022a; Anidu *et al.*, 2023;Obiefoka *et al.*, 2023).

Chemical methods such as chlorination, coagulation and physical methods are the most conventional methods of purifying water. These methods are usually expensive, not efficient and pose threats to both human and environmental health. Water purification using green nanotechnology is an alternative to chemical and physical water treatments and is environmentally friendly, benign, green, cost effective, safe, and easily sourced and scale up potable water for large scale synthesis (Okafor *et al*., 2023; Ubani *et al*., 2025).

Recently, membrane and polymers incorporated nanoparticles (NPs) which were developed for the water purification system, and NP-coated fabrics, bandages, walls, bed linen, surfaces, and medical equipment were examined as magic cure against microbial contamination (Yah and Simate, 2015). Among others, transition metal oxide NPs were deemed particularly attractive for the application of a new class of antimicrobial agents. Interestingly, several studies speculated that metals and metal oxide NPs utilize multiple mechanisms simultaneously in the microbial combating battle, placing MDR microorganisms in a critical position to develop resistance (Eltarahony *et al*., 2016).

The large-scale production of nanomaterials and their use for various agronomic applications, such as nano pesticides and nano fertilizers, as well as controlling the pathogens can also impact the ecosystem. In addition, their interaction with plants needs to be investigated (Libralato *et al*., 2016; Hasan *et al*., 2018). Moreover, tons of waste from the industry dealing with the synthesis of a variety of nanomaterials is added to the aquatic, terrestrial, and atmospheric environments that directly and indirectly impact the plants (Qasim *et al*., 2020). Plants are the primary producer of the ecosystem and play a vital role in cycling the food chain for all living organisms. Therefore, understanding the impact of nanoparticles on plant growth and development is crucial for the evaluation of potential environmental risks on food safety and human health imposed by NPs (Lehner *et al*., 2019; Hasan *et al*., 2021).

The safety of nanotreated wastewater is evaluated for phytotoxicity by observing its toxic effects on plant health and growth through standardized bioassays, typically involving model plants like cress (*Lepidium sativum*) and mustard (*Sinapis alba*). These tests help determine if the treated water is safe for potential reuse, particularly in agriculture, and identify safe dilution ratios. Phytotoxicity testing involves exposing plant seeds or seedlings to the treated wastewater under controlled conditions and comparing their development to control samples (usually distilled water) (Uba *et al*., 2021; Ifediegwu *et al*., 2023; Ubani *et al.*, 2024). Previous studies reported the nanotreatment of different water resources with focus on bacterial removal or inhibition after experiment but little or no information on isolation and characterization of possible pathogens from those sources. The available published works also did not report ecological safety evaluation of the post nanotreated surface water sources and therefore necessitated the current study. This study was undertaken to determine the disinfecting potentials and ecological safety evaluation of post - nanotreated surface water resources by biogenic silver nanoparticles using bacterial load and phytotoxicity indices.

Materials and Methods

Sample Collection

By adopting the methods of Dibua *et al*. (2020), Ibo *et al*. (2020); Chukwura *et al*. (2025); Okpalaunegbu *et al.* (2025) and Dibua *et al*. (2025a); (2025b); (2025c), the water samples used in this study were aseptically collected into 10 L sterile plastic containers at 3 different points and 5 cm depth by direct and Bellas's methods from five studied areas which include: Neni Water Shed, Orsu Ihite-Ukwa (well water), Ukwaka River, Sacred Heart Waste Water Reservoir and Ulasi River, respectively. All the sites are located in Anambra and Imo States. A representative water sample was obtained for each site by mixing samples from the individual sampling points and immediately transported to Microbiology Postgraduate Laboratory, Chukwuemeka Odumegwu Ojukwu University Uli Campus Anambra State, Nigeria laboratory for further analysis.

Specimen Collection

C. papaya was obtained from a farm in Abubor Nnewichi, Nnewi town in Nnewi North Local Government Area of Anambra State, Nigeria.

Extraction of the Plant Constituent

By adopting the methods of Shittu and Ihebunna, (2017) and Uba and Obiefuna, (2023), the moist fresh seeds of *C. papaya* were room dried for 2 weeks after cutting of the fruits and washing of the seeds with sterile clean water. The seeds were degraded to powdery form using an industrial electric blender at high-speed rate. Thereafter, 500 mL distilled water was used to dissolve 25 g weight of the *C. papaya* seed powder and heated at 80℃ for 25 min under magnetic stirring in a 1000 mL conical flask. The hot solution of the *C. papaya* seed powder was cooled and double filtered to obtain an aqueous extract which was later preserved in a refrigerator at 4℃ till further analysis.

Phytochemical Screening of the Aqueous Extract

Phytochemicals like phenols, tannins, alkaloids, terpenoids, steroids, saponins, flavonoids, glycosides, and proteins of *C. papaya* aqueous extract were tested using modified methods from various studies (Iheukwumere *et al*., 2012a; 2012b; Mundi *et al*., 2013; 2014; Okoye *et al*., 2014; Uba *et al*., 2016; Umeh *et al*., 2021; Anameze *et al*., 2023; Ezeamama *et al*., 2025a; 2025b). Results will be shown as positive (+) or negative (-).

Synthesis of the Silver Nanoparticle

The green silver nanoparticle was synthesized titrimetrically through dropwise addition of the aqueous extract into 5 mM aqueous silver nitrate ($AgNO_3$) solution under heating at 70 °C with magnetic stirrer till the observation of dark brown colour confirming silver nanoparticles synthesis (Shittu & Ihebunna, 2017; Okonkwo and Uba, 2025).

Characterization of the Synthesized Silver Nanoparticle

The physical and chemical characteristics of the synthesized green silver nanoparticle were determined using colour change formation and Ultraviolet-visible spectrophotometer (Okafor *et al*., 2023; Dokubo and Uba, 2023; Uba and Obiefuna, 2023; Ubani *et al*., 2024; Uba *et al*., 2024; Ele *et al*., 2025).

Bacteriological Analysis of Water Sample

The standard method of APHA (2012) as described by Eltarahony *et al.* (2016) and Dokubo *et al*. (2022b) was adopted in the bacteriological analysis. The presence of fecal coliforms, total coliforms, *Salmonella/ Shigella* were determined before and after treatment of the water samples using membrane filtration technique.

Disinfecting Potential Testing

In this study, the five (5) water samples were exposed with 0.5 mg/mL of the green silver nanoparticles and incubated at 30 °C for 120 min. The treated samples were taken at intervals of 30, 60 and 120 min and their bacteriological contents were determined as previously described above (Kamal *et al.,* 2020).

Isolation and Characterization of Selected Bacterial Strains

Microscopic characteristics

The standard methods for determining the gram stain and motility test as previously described by Uba (2019); Dokubo *et al*. (2022b); Alfred *et al.* (2025) and Uba *et al*., 2025 were employed in the post treatment microscopic characterization.

Biochemical characteristics

The standard methods for determining citrate, catalase, urease, nitrate reduction, methyl red- Voges Proskauer (MR-VP) test, indole test, gelatin hydrolysis and sugar fermentation test as previously described by Nwigwe *et al*. (2022), Nwigwe *et al*. (2023), Ibe *et al*. (2023), Alfred *et al.* (2023), Alfred *et al.* (2025) and Okolo *et al*. (2025) and were employed in the post treatment biochemical characterization.

Toxicity Assay

Phytotoxicity evaluation

The methods of Selim *et al.* (2012); Uba *et al*. (2021) Egurefa *et al*. (2020a), (2020b); Ubani *et al*. (2025) and Enemchukwu *et al*. (2026a); (2026b) were adopted with slight modification. The phytotoxicity of the nanoparticle treated water samples were evaluated using the seed germination technique. A monocotyledonous plant maize seeds (*Zea mays* L.) and dicotyledonous bean seeds (*Phaseolus vulgaris)* went through a floatation test to select out the non-viable seed out. After the floatation test, the viable seeds were surface sterilized by immersion in 75 % ethanol for 3 min followed by transferring in 0.001 M mercury chloride ($HgCl_2$) solution for 2 min with periodical agitation and finally thoroughly washed with sterilized distilled water to get rid of toxic chemicals. Thereafter, 10 mL of the treated water was applied to filter paper in a Petri dish and 10 sterile seeds were then placed on the filter paper. All experiments were run in triplicate. The Petri dishes were sealed with tape to minimize water loss while allowing air penetration and then incubated in the dark for 72 h at room temperature. After counting the number of germinated seeds and measuring the root length, the seed germination in distilled water was used as control. The seed germination percentage and root length of the plants in the water was determined The germination index (GI) was well as the vigour index (VI) were also determined from these variables and expressed as follows:

$$\text{Seed germination (\%)} = \frac{\text{Number of seeds germinated in the treated water}}{\text{Numcer of seeds germinated in control}} \times 100$$

$$\text{Root elongation (\%)} = \frac{\text{Mean root elongation in the growth media}}{\text{Mean root length in control}} \times 100$$

$$\text{Germination Index} = \frac{\text{Seed germination (\%)} \times \text{Root elongation (\%)}}{100}$$

Vigour index = % Germination × (mean root length + mean shoot length)

Biostatistical Management

The data obtained were statistically described in mean and standard deviation. The mean data were simultaneously subjected to two-factor analysis of variance (ANOVA) and Tukey multiple comparison test using GraphPad Prism Version 8.0.2. Statistical significance was set at the probability level less than 0.05 (Uba and Chukwura, 2016; Uba *et al*. 2018a; 2018b; 2018c; Uba, 2019a; 2019b; 2019c; Uba *et al*. 2019b; 2019c; 2019d; 2019e; Alisa *et al*., 2020; Anukam *et al*., 2020a; 2020b;

Uba *et al*., 2020a; 2020b; 2020c; 2020d; 2020e; 2020f; 2020g; Uba e*t al.*, 2021a; 2021b; Ifediegwu *et al*. 2023a; 2023b; 2024a, 2024b; 2024c; Nnaka *et al*. 2024).

Results and Discussion

The phytochemical characteristics of the two plants used: *C. papaya* and *M. oleifera* were summarized in the Table 1. The results revealed the presence of some active compounds in the plants. From the table, it could be seen that flavonoids, terpenoid, saponins were present in both plants. Glycosides, steroids, phenols, tannins, alkaloids and steroids were present in *C. papaya* but absent in *M. oleifera* while Protein was present in *M. oleifera* but absent in *C. papaya*, respectively. *M. oleifera* and *C. papaya* seed extract's phytochemicals matched with previous reports by Uba and Obiefuna *et al*. (2023) and Ubani *et al*. (2024) showing these bioactive compounds are abundant and give the extract its unique properties.

Table 1: Phytochemical constituents of the aqueous seed extracts of *C.papaya* and *M. oleifera*

Constituents	*C. papaya*	*M. oleifera*
Phenols	+ve	+ve
Tannins	+ve	+ve
Alkaloids	+ve	+ve
Terpenoids	+ve	+ve
Steroid	+ve	-ve
Saponin	+ve	+ve
Flavonoid	+ve	+ve
Glycosides	+ve	-ve
Protein	-ve	+ve

Keys: +ve = positive result for a test; - ve = Negative result for the test

The result in Figures 1A - C and 2 demonstrated the sequentially formations of silver nanoparticles. It can be seen that there was colourless appearance of silver nitrate solution at the beginning of the synthesis but later precipitated to brownish then to dark brown colour appeared after 24 hr upon constant heating on magnetic stirrer at 70 °C confirming the successful synthesis. The dark brown colour emerged from Ag^{+} reducing to Ag^{0} due to *C. papaya and M. oleifera* seed extract's bioactive compounds and corroborated with the published works of Dokubo and Uba (2023) and Uba and Okonkwo (2025) who reported several bioactive ingredients as the reducing and stabilizing agents during silver nanoparticle formation.

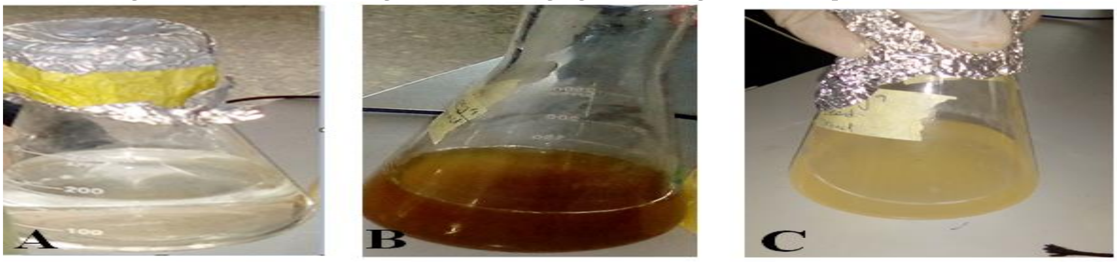

Figure 1: (A) Silver nitrate ($AgNO_3$) solution (B) *C. papaya* aqueous seed extract and (C) *M. oleifera* aqueous seed extract

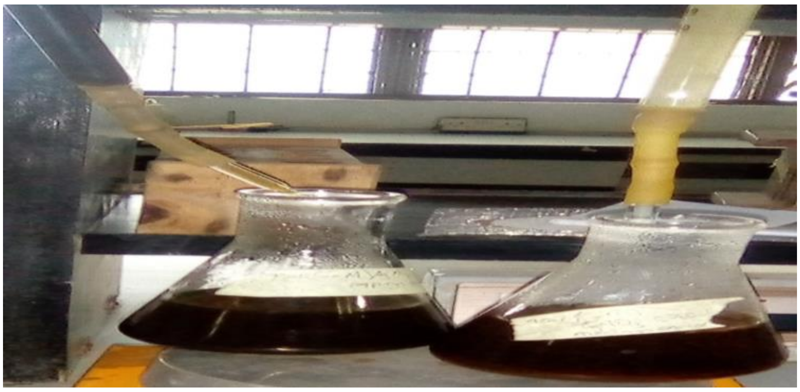

Figure 2: Silver nanoparticle synthesis

The UV-VIS spectroscopy revealed absorbency peaks of both *C. papaya* and *M. oleifera* synthesized AgNPs in the range from 200 to 800 nm (Figure 3 A - B). From the figures, the maximum peak of both AgNPs was at 400 nm each while the minimum peaks were at 800 nm and 700 nm, respectively. These colour changes that occurred at the peak absorbances could be due to surface plasmon activation on the silver nanoparticles by the electromagnetic field (Uba and Okonkwo, 2025). There have reports of silver nanoparticle having wavelength of 400 - 500 nm thereby upholding the findings obtained in the present study.

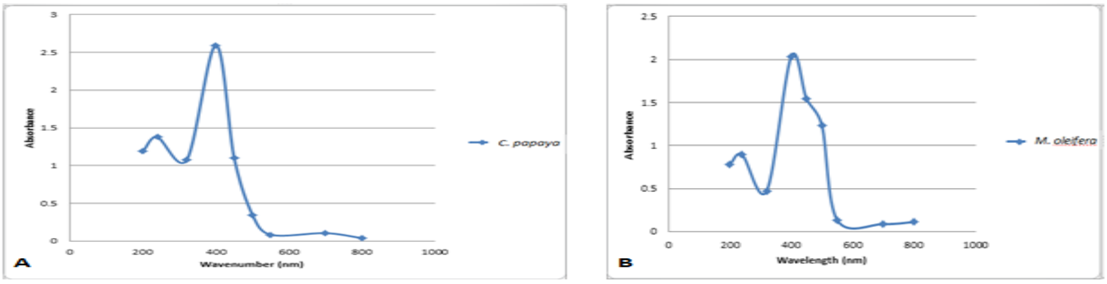

Figure 3: (A) UV-VIS spectral of *C. papaya* (B) UV-VIS spectral of *M. oleifera*

The results of the bacterial load indices of the treated and untreated water samples are presented in Table 2. From the Table 2, the agent *M. oleifera* had the lowest count (02 CFU) in the sample D and the agent *C. papaya* had the highest count (110 CFU) in sample C. Also, the result in Table 2 revealed that *M. oleifera* and *C. papaya*-synthesized silver nanoparticles effectively reduced bacteria count in water samples, likely due to increased pH and altered physicochemical properties, damaging bacterial cells and disrupting the metabolic activity and corroborated with the published works of Kamal *et al*. (2020); Dokubo and Uba (2023) and Uba and Okonkwo (2025) who observed significant reduction in bacteria loads of their treated water samples. The nanoparticles' effect increased with contact time (30 - 120 min) showing time dependence ($P < 0.05$).

The result of the biochemical and microscopic profile of the bacterial strains isolated from the water samples is presented in Table 3. From the table, most isolates were positive to citrate, H_2S production, motility, urease, nitrate, fructose, maltose, mannitol, xylose, galactose, indole tests and negative to Voges-Proskauer, urease, mannitol, xylose, galactose ad indole. The biochemical test as shown in Table 4 revealed that the bacterial strains were all Gram negative short rods and classically identified using Bergeys' manual as *Klebsiella pneumoniae, Enterobacter aerogenes* and *Escherichia coli* as the indigenious possible bacterial pathogens. All the isolates were Gram negative short rods with *Klebsiella pneumoniae* as the dominant species and aligned with Dokubo *et al*. (2022a), Dokubo *et al*. (2022b), Alfred *et al*. (2025) and Uba *et al*. (2025) who identified these bacterial strains from different water sources.

Phytotoxicity testing is a crucial, high-sensitivity, and environmentally relevant method for evaluating the safety, efficacy, and ecological impact of water treated with nanotechnology (nanotreated water). The result of the percentage seed germination of *Zea mays and P. vulgaris* when exposed to water sample treated with biosynthesized silver nanoparticles and calcium hypochlorite is shown in Figure 4. From the figure, sample C of *C. papaya* synthesized treated water and sample E of *M. oliefera* synthesized treated water had the highest (93.75 %) percentage seed germination in *Zea mays* and the lowest (37.5 %) is from sample D of *M. oleifera* synthesized treated water. While sample B of *M. oleifera* had the highest (83.33 %) and and both sample D and E of *C. papaya* had lowest (16.6 %) percentage seed germination in *P. vulgaris*, respectively. The result of the percentage root length of *Zea mays and P. vulgaris* when exposed to water sample treated with biosynthesized silver nanoparticles and Calcium hypochlorite is shown in Figure 5. From the figure, sample B of *M. oleifera* synthesized treated water had the highest (86.21 %) and sample E of *C. papaya* had the lowest (54.48 %) percentage root length. While sample D of *C. papaya* had the highest (90 %) percentage and sample B, D of *M. oleifera* and sample D of $CaOCl_2$ had the lowest (30 % respectively) percentage root length in *P. vulgaris*, respectively. The result of the germination index of *Zea mays and P. vulgaris* when exposed to water sample treated with biosynthesized silver nanoparticles and calcium hypochlorite is shown in Figure 6. From the figure, sample A of *C. papaya* had the highest (68.19 %) and sample D of *M. oleifera* had the lowest (29.74 %) germination index in *Zea mays*. While sample C of $CaOCl_2$ had the highest (45.83) and sample E of *C. papaya* had the lowest (6.66 %) germination index in *Phaseolus vulgaris*. The result of the vigor index of *Zea mays and P. vulgaris* when exposed to water sample treated with biosynthesized silver nanoparticles and Calcium hypochlorite is shown in Figure 7. From the Figure, sample B of *M. oleifera* had the highest (1284.98) and sample D of *C. papaya* had the lowest (604.57) vigor index in *Zea mays*. While sample C of *M. oleifera* had the highest (350.62) and sample E of *C papaya* had the lowest (53.28) germination index in *Phaseolus vulgaris*. Summarily for the toxicity testing, the treated water was effective in plant growth except a stunted seed growth of *Phaseolus vulgaris* in *C. papaya* treatment set ups but grew massively in *M. oleifera* silver nanoparticles treatment set ups. The germination index accounted for both low toxicity which affects root growth and high toxicity, which affects seed germination of *Zea mays* L. and *Phaseolus vulgaris* and the possible reason could be the toxicity of AgNPs is due to the bioaccumulation of silver ions (Ag^+ ions) that lower the production of chlorophyll, ultimately reducing the photosynthesis and impacting the cell growth (Zhang *et al*., 2019). Hassan *et al*. (2021) reported that moderate concentrations of AgNPs have a stimulatory effect on seedling growth of lettuce seed, while higher concentrations induced inhibitory effects due to the release of Ag^+ ions.

Table 2**:** Disinfecting potential of the biosynthesized silver nanoparticle on treated and control fresh water sample

Culture Media	**Water sample**	**Control (Colony/100 mL)**	**Treated (Colony/100 mL)** *M. oleifera* **(Min)**			*C. papaya* **(Min)**			**Calcium hypochlorite ($CaOCl_2$) (Min)**		
			30	60	120	30	60	120	30	60	120
EMBA	Neni Water Shed	31.0±1.00	10.7±0.32	38.7±0.31	22.5±0.22	28.0±0.70	20.0±0.70	13.0±1.41	41.9±0.40	38.7±0.42	45.2±0.24
	Orsu Ihite-Ukwa well water	91.0±1.53	19.7±0.12	63.7±0.56	82.4±0.32	46.0±4.40	27.0±1.53	26.0±0.58	75.8±0.48	86.8±0.06	80.2±0.23
	Ukwaka River	318.0±4.51	93.1±0.53	69.2±0.01	95.9±0.32	110.0±1.68	80.0±0.02	29.0±0.36	55.9±0.08	64.2±0.02	69.2±0.64
	Sacred heart waste water reservoir	112.0±3.00	98.2±0.04	94.6±0.05	85.7±0.06	70.0±1.17	26.0±0.03	18.0±1.32	87.5±0.04	89..3±0.01	89.2±0.05
	Ulasi River	162±2.52	40.7±0.04	93.2±0.08	91.4±0.06	09.0±0.34	17.0±0.12	19.0±1.41	95.7±0.07	93.2±0.03	93.8±0.00
MCA	Neni Water Shed	362.0±1.73	28.2±0.02	33.7±0.05	52.2±0.06	163.0±1.00	151.0±2.08	134.0±2.65	95.6±0.01	97.2±0.01	96.4±0.02
	Orsu Ihite-Ukwa well water	53.0±3.61	75.5±0.18	52.8±0.19	47.2±0.67	33.0±4.27	35.0±1.27	27.0±4.89	69.8±0.15	69.8±0.63	77.4±0.08
	Ukwaka River	305.0±3.56	94.1±0.46	93.1±0.08	79.3±0.04	72.0±3.26	70.0±1.48	51.0±00	95.7±0.07	97.3±0.35	97.7±0.29
	Sacred heart waste water reservoir	120.0±2.00	80±0.01	86.7±0.14	88.3±0.03	73.0±4.62	50.0±3.43	40.0±1.76	79.2±0.08	76.7±0.37	58.3±0.11
	Ulasi River	328.0±2.00	92.9±0.11	69.2±0.57	70.1±0.43	200.0±3.21	189.0±2.08	146.0±1.07	90.9±0.67	81.7±0.43	91.5±0.77
SSA	Neni Water Shed	344.0±2.52	71.2±0.77	75.6±0.38	72.1±0.35	173.0±1.25	101.0±4.93	89.0±1.53	27.0±0.21	28.0±0.48	41.0±1.33
	Orsu Ihite-Ukwa well water	220.0±3.51	59.1±0.04	87.3±0.01	73.6±0.03	10.0±1.68	24.0±1.53	16.0±2.52	56.8±0.02	91.4±0.22	90.5±0.08
	Ukwaka River	180.0±2.52	72.2±0.61	83.9±0.08	77.8±0.02	14.0±2.34	23.0±1.76	45.0±3.41	89.4±0.04	95.6±0.03	90.0±0.04
	Sacred heart waste water reservoir	39.0±2.08	61.5±0.72	43.6±0.78	23.1±0.43	17.0±3.9	12.0±1.43	06.0±3.78	28.2±0.12	30.8±0.73	53.9±0.50
	Ulasi River	318.0±3.51	92.8±0.57	93.7±0.31	94.0±0.01	15.0±2.34	13.0±1.76	18.0±0.12	90.9±0.02	92.5±0.08	90.6±0.03

Key: EMB = Eosine Methylene Blue Agar; MCA = MacConkey Agar; Salmonella Shigella Agar; mL = Millilitre

Table 3: Biochemical and microscopic profile of the bacterial strains isolated from the water sample

	Isolate code					
Test	EMB1	EMB2	SSA1	SSA2	MAC1	MAC2
Gram reaction	-ve	-ve	-ve	-ve	-ve	-ve
Morphology	Short rods	Short rods	Short rods	Short rods	Short rods	Short rods
Motility	+ve	+ve	+ve	+ve	+ve	+ve
Citrate	+ve	+ve	+ve	+ve	+ve	+ve
Urease	+ve	-ve	+ve	-ve	+ve	-ve
Nitrate reduction	+ve	+ve	+ve	+ve	+ve	+ve
M R	+ve	+ve	+ve	+ve	+ve	+ve
V P	+ve	+ve	-ve	-ve	-ve	-ve
Indole	-ve	+ve	+ve	+ve	-ve	+ve
Maltose	+ve	+ve	+ve	+ve	+ve	+ve
Fructose	+ve	+ve	+ve	+ve	+ve	+ve
Xylose	+ve	+ve	+ve	-ve	-ve	-ve
Mannitol	+ve	-ve	-ve	+ve	+ve	+ve
Galactose	+ve	+ve	+ve	-ve	-ve	-ve
Identities	*Klebsiella pneumoniae*	*Enterobacter aerogenes*	*Klebsiella pneumoniae*	*Enterobacter aerogenes*	*Klebsiella pneumoniae*	*Escherichia coli*

Key: MAC = MacConkey Agar, EMB = Eosin Methylene Blue Agar, SSA = *Salmonella-Shigella* Agar, -ve = negative, +ve = positive, H_2S= hydrogen sulfide, MR = Methyl red, VP = Voges-Proskauer

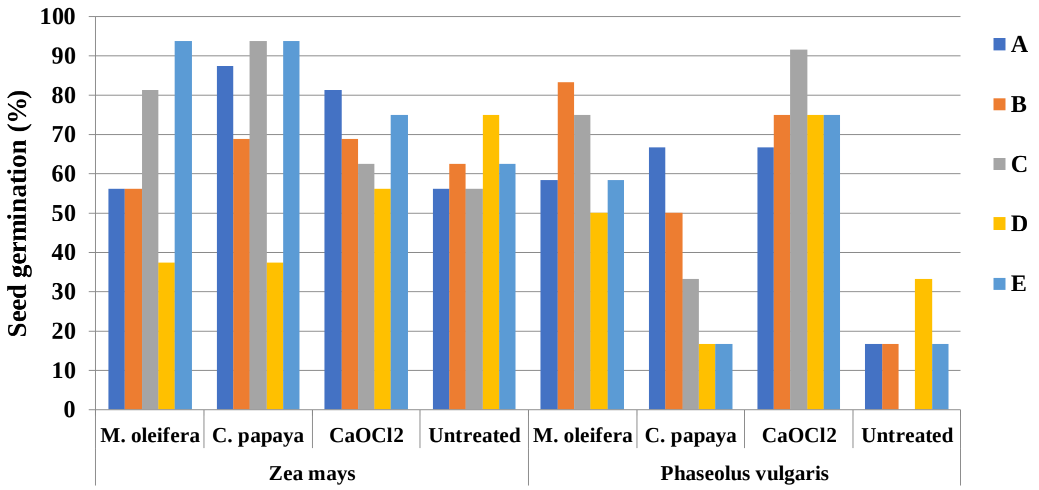

Figure 4: Percentage seed germination of of *Zea mays* and *Phaseolus vulgaris* when exposed to water sample treated with biosynthesized silver nanoparticle.

Key: A= Neni watershed, B = Well water from Orsu-ihitteukwa, C = Ukwaka river, D = Wastewater reservoir Sacred heart Uli, E = Ulasi river, $CaOCl_2$ = Calcium hypochlorite, % = Percentage

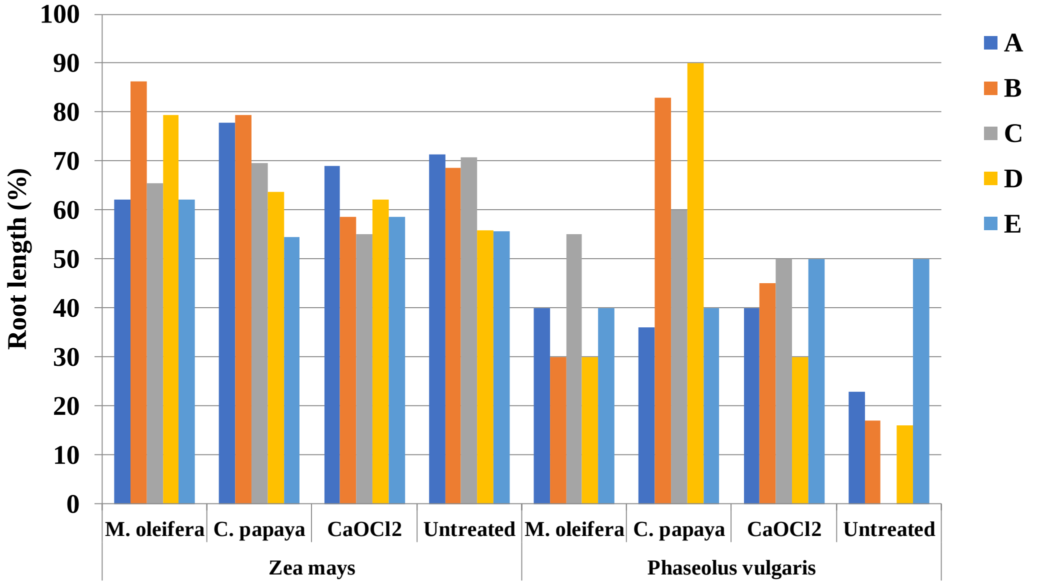

Figure 5: Percentage root length of of *Zea mays* and *Phaseolus vulgaris* when exposed to water sample treated with biosynthesized silver nanoparticle.

Key: A= Neni watershed, B = Well water from Orsu-ihitteukwa, C = Ukwaka river, D = Wastewater reservoir Sacred heart Uli, E = Ulasi river, $CaOCl_2$ = Calcium hypochlorite, % = Percentage

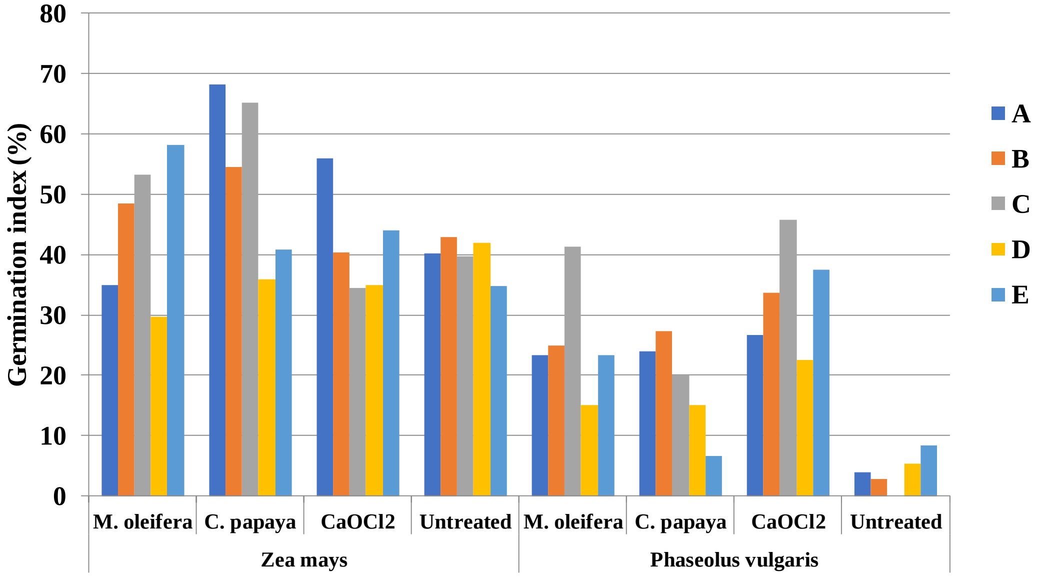

Figure 6: Germination index of of *Zea mays* and *Phaseolus vulgaris* when exposed to water sample treated with biosynthesized silver nanoparticle.

Key: A= Neni watershed, B = Well water from Orsu-ihitteukwa, C = Ukwaka river, D = Wastewater reservoir Sacred heart Uli, E = Ulasi river, $CaOCl_2$ = Calcium hypochlorite, % = Percentage

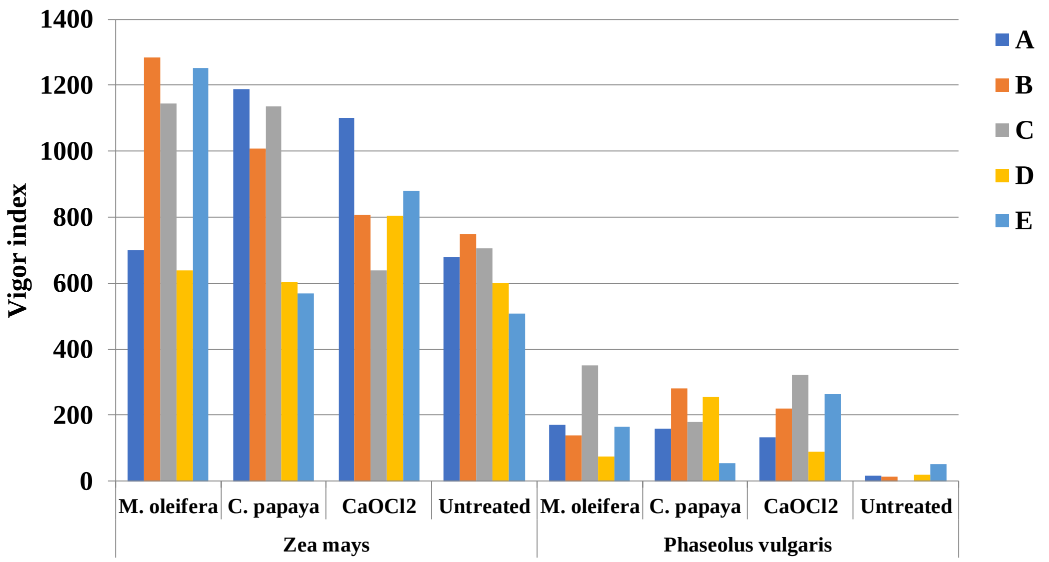

Figure 7: Vigor index of of *Zea mays* and *Phaseolus vulgaris* when exposed to water sample treated with biosynthesized silver nanoparticle.
Key: A= Neni watershed, B = Well water from Orsu-ihitteukwa, C = Ukwaka river, D = Wastewater reservoir Sacred heart Uli,
E = Ulasi river, $CaOCl_2$ = Calcium hypochlorite, % = Percentage

Conclusion

In conclusion, the aqueous seed extract of *C. papaya* successfully synthesized silver nanoparticles by reducing silver nitrate ($AgNO_3$) to elemental nanometal form likely due to the presence of hydroxyl groups which act as capping and reducing agents during nanoparticles formation. This synthesized nanoparticles was able to significantly reduced the microbial load in water samples and also makes the treated surface water resources less toxic for environmental usage for at least after treatment time of 120 min.

References

Alfred, P.N., Mbachu, I.A.C. and Uba, B.O. (2023). Water Quality Indices and Potability Assessment of Three Streams in Akwa North and South Local Government Areas, Anambra State, Nigeria. *Journal of Applied Sciences and Environmental Management* 27 (2):223 – 228. https://dx.doi.org/10.4314/jasem.v27i2.6.

Alfred, P. N., Mbachu, I. A. C., Uba, B. O., Iweriolor, S.N. and Okemadu, O.C. (2025). Bacterial Pathogen Community Profiling of Three Freshwater Bodies in Akwa North and South Local Government Areas, Anambra State, Nigeria. *IPS Journal of Public Health*, 5 (3): 302 - 309. https://doi.org/10.54117/rrrmk019.

Alisa, O. C., Anukam, N. B., Ogukwe, N. C., Chinwuba, J. A. and Uba, B. O. (2020). Determination of compost humification and other constituents that can be used as stability index. *International Research Journal of Modernization in Engineering Technology and Science*, 2 (12): 139 – 147. https://www.irjmets.com/paperdetail.php?paperId=47fd0a18a604b911124f7def72690f1c.

Anameze, C.I., Emmy-Egbe, I.O., Anyaegbunam, L.C., Ogomaka, I.J., Uba, B.O., Odumodu, O.A., Ezeigwe, C., Kamalu, N.L., Chukwubude, C.B., Akogu, O., Ezekwueme, E., Emmy-Egbe, C.C., Obiefoka, O.S., Ezenwata, S.I. and Ilechukwu, C.C. (2023). Qualitative and quantitative phytochemical analysis of *Gongronema latifolium* leaf extract. *IPS Journal of Applied Microbiology and Biotechnology* 2 (1): 16 – 19. https://doi.org/10.54117/ijamb.v2i1.10.

Anidu, F.N., Uba, B.O., Ezemba, C.C., Okoye, E.L. and Dokubo, C.U. (2023). Study on optimization, degreasing and destaining potentials of glycophospholipid biosurfactant produced by *Bacillus* anthracis S62A. *Dutse Journal of Pure and Applied Sciences* 9 (1a): 29 – 43. https://dx.doi.org/10.4314/dujopas.v9i1a.4.

Anukam, N. B., Alisa, O. C., Ogukwe, N. C., Chinwuba, J. A., Uba, B. O. and Ogukwe, E. C. (2020a). Phyto – toxicity evaluation of agro – waste formulated compost on five different plant seeds. *The International Journal of Engineering and Science*, 9 (12): 21 -26. C0912012126.pdf Or https://dx.doi.org/10.9790/1813-0912012126.

Anukam, N. B., Alisa, O. C., Ogukwe, N. C., Chinwuba, J. A., Uba, B. O. and Ogukwe, E. C. (2020b). Physico–chemical evaluation of agro–waste formulated compost from five different waste source. *American Journal of Applied Chemistry*, 8(6): 130 – 134. oi: https://dx.doi.org/10.11648/j.ajac.20200806.11.

Chukwura, E. I., Uba, B. O., Dibua, N. A., Chude, C. O., Okoye, E. C. S., Ubajekwe, C.C., Eleanya, L. C., Agbo, B. C. and Nwajiobi, F. O. (2025). Physicochemical and bacteriological quality assessment of Ogbunike abattoir wastewater Anambra State, Nigeria for irrigation purpose. *Journal of Global Ecology and Environment* 21 (3): 378 – 385. doi.10.56557/jogee/2025/v21i39625.

Dokubo, C. U., Uba B. O., Nnubia, C.P. and Akaun, I.P. (2022a). Evaluation of toxicity and resistant effects of heavy metals and antibiotics on the growth of marine bioluminescent bacteria. *International Journal of Frontline Research in Science and Technology* 01 (02): 030 – 037. https://doi.org/10.56355/ijfrst.2022.1.2.0041.

Dokubo, C. U., Uba B. O. and Nnaji, I. G. (2022b). Combined coagulation and disinfection efficiencies of *Mangifera indica*, *Carica papaya* and solar disinfection on synthetic agro - waste water. *International Journal of Advanced Multidisciplinary Research and Studies* 2 (4):789 - 793. https://www.multiresearchjournal.com/arclist/list-2022.2.4/id-437.

Dokubo, C.U. and Uba, B.O. (2023). Assessment of the decontamination and disinfecting potentials of *Ocimum gratissimum* synthesized silver nanoparticles on water and wastewater samples. *IPS Journal of Public Health* 3 (2): 58 – 65. https://doi.org/10.54117/ijph.v3i2.20.

Dibua N. A., Chukwura E.I & Chude C.O. (2020) Evaluation of Different salts and Heavy Metal Concentrations on Bacterial Biofilm from Selected Surface and Borehole Water Samples. *Frontiers in Environmental Microbiology*. 6 (2): 11-17.

Dibua, N.A., Nwose, C. V., Chude, C. O., Eleanya, L. C., Okoye, E. C.S., Agbo, B. C. & Nwerenkem, O. S. (2025a). Physicochemical and Bacteriological Quality of Borehole Water Near Dumpsites in Student Hostels, Uli Campus, Nigeria. *Asian Journal of Microbiology and Biotechnology* 10 (2):1-10.

Dibua, N.A., Ezeanwu, B. A., Chude, C. O., Eleanya, L. C., Okoye, E. C., Adamu, J. E., Agbo, B. C., Okpala, V. C., Oradubanya, O., K. and Ngonadi, U. J. (2025b). Heavy Metal Assessment of *Claris Angullaris* and *Tilapia Zilli* from Omambala River, Anambra State, Nigeria. *Journal of Global Agriculture and Ecology* 17 (3):19-30.

Dibua, N. A., Okoye, E. C. S., Egudu, N. A., Chibueze, C. B., Azuka, C. P., Ojeah, I. K., & Nwosu, O. K. (2025c). Assessment of physicochemical parameters and heavy metals concentration of leachates from dumpsite around Idemili River, Obosi Nigeria. *Archives of Agriculture and Environmental Science*, 10(2), 364 - 373.

Egurefa, S.O., Orji, M.U. and Uba, B.O. (2020a). Toxic effect of refinery industrial effluent using three toxicity bioassays. *South Asian Journal of Research in Microbiology*, 6 (2): 10 – 23.

Egurefa, S.O., Orji, M.U. and Uba, B.O. (2020b). Toxicological evaluation of two Nigerian refinery effluents using natural biomonitors. *Research & Reviews: A Journal of Toxicology*, 10 (2): 22 – 31.

Ele, E.E., Okoye, E.L., Uba, B.O., Aniekwu, C.C., Iheukwumere, C.M., Obumseli, H. and Okoye, P.A. (2024). Antibacterial effects of phytofabricated silver nanoparticles against some selected bacteria. *International Journal of Research and Innovation in Applied Science* 9 (10): 460 – 467. https://doi.org/10.51584/IJRIAS.

Eltarahony, M., Zaki, S., Kheiralla, Z.H. and Abd-El-Haleem, D. (2016). Bioconversion of silver and nickel ions into nanoparticles By *Achromobacter* sp. strain MMT and their application in wastewater disinfection. *International Journal of Recent Scientific Research* **7** (2): 8838 − 8847. https://doi.org/10.1155/2018/5263814

Enemchukwu, C. N., Lukong, C. B., Nwaka, A. C., Uba, B. O., Ifemeje, J. C., Mere, C. A., & Igiri, V. C. (2026a). Green synthesis of eco-friendly potassium nanoparticles immobilized lipase enzyme and its potentials in biodiesel production. *International Journal of Global Trends and Research*, 3 (1): 66 – 76. https://doi.org/10.54117/n3bqr651.

Enemchukwu, C. N., Lukong, C. B., Nwaka, A. C., & Uba, B. O. (2026b). Isolation of Lipase from Soyabean Seeds and Its Immobilization in Calcium Alginate Beads. *IPS Journal of Biotechnology and Applied Biochemistry*, 2(1), 93–100. https://doi.org/10.54117/ijbab.v2i1.118.

Ezeamama, M. M. C., Chukwura, E. I., Uba, B. O ., Chikwendu, J. C., Ubajekwe, C. C., Ike, V. E., & Egbe, P. A. (2025a). Evaluation of the Urease Inhibitory, Antiulcer and Acute Toxicity Effects of Ethanolic Seed Extracts of *Garcinia Kola* against Chemically Induced Ulcers. *IPS Journal of Phytochemistry and Medicinal Plant Research*, 1(2): 20 – 26. https://doi.org/10.54117/ijpmpr.v1i2.4.

Ezeamama, M. M. C., Chukwura, E. I., Uba, B. O., Iheukwumere, I. H., Awari, V. G., Ike, V. E., & Agu, K. C. (2025b). Assessment of the Phytochemical and Antibacterial Profiles of Aqueous and Ethanolic Extracts of *Garcinia Kola* Seed. *IPS Journal of Drug Discovery Research and Reviews*, 3(2): 51 – 56. https://doi.org/10.54117/ijddrr.v3i2.39.

Hasan, M.; Ullah, I.; Zulfiqar, H.; Naeem, K.; Iqbal, A.; Gul, H.; Ashfaq, M. and Mahmood, N. (2018). Biological entities as chemical reactors for synthesis of nanomaterials: Progress, challenges and future perspective. *Material and Today Chemistry*, 8: 13–28.

Hasan, M., Mehmood, K., Mustafa, G., Zafar, A., Tariq, T., Hassan, S. G., Loomba, S., Zia, M., Mazher, A., Mahmood, N., & Shu, X. (2021). Phytotoxic Evaluation of Phytosynthesized Silver Nanoparticles on Lettuce. *Coatings*, 11(2), 225. https://doi.org/10.3390/coatings11020225.

Ibe, C.O., Mbachu, I.A.C. and Uba, B.O. (2023). Analysis and characterization of untreated greywater obtained from Enugu Metropolis. *Tropical Journal of Applied Natural Sciences* 1 (1): 1 – 17. https://tjansonline.org/view-paper.php?id=20.

Ibo, E.M., Umeh, O.R., Uba, B.O. and Egwuatu, P.I. (2020). Bacteriological assessment of some borehole water samples in Mile 50, Abakaliki, Ebonyi State, Nigeria. *Archives of Agriculture and Environmental Science* 5 (2): 179 – 189. https://doi.org/10.26832/24566632.2020.0502015.

Ifediegwu, M. C., Uba, B.O., Awari, V., Chukwujekwu, A. G. and Akaun, I. P. (2023a). Post-reclamation evaluation of residual hydrocarbons in crude oil contaminated soil using gas chromatographic techniques and plant growth indices. *Journal of Pollution Monitoring, Evaluation Studies and Control*, 2 (1): 15 - 29.

Ifediegwu, M. C., Onuora, S. C., Uba, B.O., Okoye, E. L., Egurefa, S. O. and Awari, V. G. (2023b). Assessment of the plasmid mediated biodegradation of crude oil under optimal growth conditions. *IPS Interdisciplinary Journal of Biological Sciences*, 2(1): 32 – 44.

Ifediegwu, M.C., Uba, B.O., Awari, V.G. and Okongwu, D.J. (2024a). Biodegradation of bonny light crude oil by plasmid and non-plasmid borne soil bacterial strains using biostimulation and bioaugmentation techniques. *Science World Journal*, 19 (1): 178 – 188.

Ifediegwu, M.C., Orji, M.U., Onuorah, S.C. and Uba, B.O. (2024b). Evaluation of the degrading potentials of plasmid and non–plasmid borne soil bacterial strains on Bonny light crude oil. *Archives of Agriculture and Environmental Science* 9(1): 14 – 22.

Ifediegwu, M.C., Orji, M.U., Onuorah, S.C. and Uba, B.O. (2024c). Exploration of the catabolic plasmid genes profile of crude oil degrading bacteria isolated from aged oil contaminated soils of Anambra State. *Scientia Africana*, 23 (1): 11 – 30.

Iheukwumere, I., Uba, B.O. and Ubajekwe, C.C (2012). Antibacterial activity of *Annoria muricate jmmmn* and *Persca americana* leaves extracts against ampicillin resistant *S. aureus*. *Journal of Science, Engineering Technology*, 19(2): 10786-10798.

Iheukwumere, I., Uba, B.O. and Ubajekwe, C.C (2012). Anti-fungal, haematological and wound healing activity of *Mucuna pruriens* leaves extracts. *Journal of Applied Science*, 15(2): 10541-10550.

Kamal, A., Zaki, S., Shokry, H. and Abd-El-Haleem, D. (2020). Using ginger extract for synthesis of metallic nanoparticles and their applications in water treatment. *Journal of Pure and Applied Microbiology* 14 (2):1227−1236.https://doi.org/10.22207/JPAM.14.2.17.

Libralato, G.; Costa Devoti, A.; Zanella, M.; Sabbioni, E.; Mičetić, I.; Manodori, L.; Pigozzo, A.; Manenti, S.; Groppi, F. and Volpi,G.A.(2020).Phytotoxicity of ionic, micro- and nano-sized iron in three plant species. *Ecotoxicology and Environmental Safety*,123: 81–88.

Megersa, M., Beyene. A., Ambelu, A. and Triest, L. (2018).Comparison of purified and crude extracted coagulants from plant species for turbidity removal. International *Journal of Environmental Science and Technology*, 1 − 10.

Mundi, K.S., Okoye, E.L., Uba, B.O., Esimone, C.O. and Attama, A.A. (2013). Evaluation of the antibacterial activity of some commercial disinfectants against methicillin-resistant *Staphylococcus aureus*. *International Journal of Applied Science and Engineering* 1 (1): 19 – 22. http://dx.doi.org/10.2139/ssrn.3448993.

Mundi, S.K; Okoye, E.L., Uba, B.O., Esimone, C.O, and Attama, A.A. (2014). The combined antibacterial activity of face cleaning agent and *Psidium guajava* leaf extract on methiciliin resistant *Staphylococcus aureus*. *International Journal of Agriculture and Biosciences* 3 (2): 77 – 81. https://www.ijagbio.com/pdf-files/volume-3-no-2-2014/77-81.pdf.

Nwigwe, V.N. and Uba, B.O. (2022). Role of electrochemically active bacteria in the treatment of piggery and poultry wastewaters from Umuagwo in Ohaji Egbema Local Government Area of Imo State, Nigeria. *Journal Applied Science and Environmental Management* 26 (12): 2085 – 2093. https://dx.doi.org/10.4314/jasem.v26i12.24.

Nwigwe, V. N., Nwigwe, H. C., Okereke, J. N., Uba, B.O. and Dokubo, C.U. (2023). Potential of agro-based industrial wastewater as an alternative substrate for bioelectricity. *Animal Research International* 20 (1): 4741 – 4747.https://www.ajol.info/index.php/ari/article/view/246974.

Nnaka, O. B., Umeaku, C.N., Uba, B.O., Anyene, C. C. and Nkachukwu, M. B. (2024). Determination of the effect of mycoremediation on the physicochemical properties of hydrocarbon polluted soils of the Niger Delta region of Nigeria. *Tropical Journal of Applied Natural Sciences*, 2 (1): 1 – 18.

Obiefoka, S.O., Emmy-Egbe, I.O., Anyaegbunam, L.C., Uba, B.O., Anameze, C.I., Ogoamaka, I.J., Kamala, N.L., Ezeigwe, C., Akaogu, O., Odumodu, O.A., Emmy-Egbe, C.C., Ezenwata, O.S. and Chukwubude, C.B. (2023). The Prevalence of Lymphatic Filariasis Infection among Primary School Children (5-9 Years) of Infected Adults in Ihiala Local Government Area of Anambra State, Nigeria. *IPS Journal of Public Health*, 3 (2): 66 - 72.

Obiefuna, O. H., Nzekwe, C. M., Onuorah, S. C., Uba, B. O., Ubajekwe, C. C., Okey-Ndeche, N. F., and Ike, V. E. (2025). Assessment of the seasonal impact on physicochemical quality of borehole water samples in Emene, Enugu State, Nigeria. *IPS Journal of Public Health* 5 (4): 422 – 430. https://doi.org/10.54117/8rr3ms81

Okafor, C. A., Uba, B.O. and Dokubo, C.U. (2023). Application of myco-fabricated silver nanoparticle in the adsorption malachite green and trypan blue from aqueous solution. *Nigerian Journal of Life Sciences* 12 (2): 8 – 15. https://doi.org/10.52417/njls.v12i2.354.

Okolo, O.C., Uba, B. O. and Ike, V.O. (2025). Influence of untreated noodle wastewater on physicochemical, enzymatic and bacteriological dynamics of soil. (2025). *Journal of Pollution Monitoring, Evaluation Studies and Control* 4 (2): 110 –119. https://doi.org/10.54117/jpmesc.v4i2.20.2025.

Okoye, E.L., Uba, B.O., Uhobo, P.C., Oli, A.N. and Ikegbunam, M.N. (2014). Evaluation of the antibacterial activity of methanol and chloroform extracts of *Alchornea cordifolia* leaves. *Journal of Scientific Research and Report* 3 (1):255 – 262. https://journaljsrr.com/index.php/JSRR/article/view/1692/3353.

Okpalaunegbu, C.A., Chinweuba, A.J., Ojiako, E.N., Uba, B.O. and Okafoanyali, J.O. (2025). Physicochemical properties and heavy metal analysis of sewage and leachate wastewater collected from the Sewage Tank at the University of Nigeria, Nsukka and the First Market Municipal Dumpsite, Ifite-Awka, Anambra State. *Journal of Global Ecology and Environment* 21 (3): 320 – 332. https://doi.org/10.56557/jogee/2025/v21i39583.

Qasim, S.; Zafar, A.; Saif, M.S.; Ali, Z.; Nazar, M.; Waqas, M.; Haq, A.U.; Tariq, T.; Hassan, S.G.; Iqbal, F. et al. (2020). Green synthesis of iron oxide nanorods using Withania coagulans extract improved photocatalytic degradation and antimicrobial activity. *Journal of Photochemistry and Photobiology*, B : 204.

Shittu, K.O. and Ihebunna, O. (2017). Purification of simulated waste water using green synthesized silver nanoparticles of *Piliostigma thonningii* aqueous leave extract. *Advances in Natural Sciences: Nanoscience and Nanotechnology* 8 (045003): 1 − 9. https://doi.org/10.1088/2043-6254/aa8536

Uba, B.O., Uhobo, P.C., Oli, A.N. and Ikegbunam, M.N. (2014). Evaluation of the antibacterial activity of methanol and chloroform extracts of *Alchornea cordifolia* leaves. *Journal of Scientific Research and Report,* 3 (1):255-262. https://journaljsrr.com/index.php/JSRR/article/view/1692/3353.

Uba, B.O., Okoye, E.L. and Chukwura, E.I. (2016). Bioremediating potentials of marine mercury-resistant bacteria on polyaromatic hydrocarbons components of Bonny light crude oil. *Journal of Advances in Biology and Biotechnology*, 7 (4): 1- 12.

Uba, B. O., Okoye, E. L., Ekwueme, C., Azubike, T. C. and Ugoma, J.C. (2017). Heavy metals and antibiotics resistance pattern of bacteria isolated from brewery and plastic industries effluent waste. *African Journal of Education, Sciences and Technology,* 3(3): 43 – 50.

Uba, B. O. (2018a). Effect of aromatic hydrocarbons and marine sediments from Niger Delta on the growth of microalga *Phaeodactylum tricornutum*. *Biotechnology Journal International*, 22 (4): 1 – 18.

Uba, B. O. (2018b). Growth profile and catabolic pathways involved in degradation of aromatic hydrocarbons by marine bacteria isolated from Niger Delta. *Microbiology Research Journal International*, 26 (5): 1 - 18.

Uba, B. O., Chukwura, E. I., Okoye, E. L., Ubani, O., Irabor, M. I., Onyekwuluje, N. V., Ajeh, J. E., Muogbo, C. S., Nwafor, M. C., Igboesorom, C. C., Nwodo, C. J., Okafor, J. C. and Nwachukwu, C. J. (2018a). Multiple degradation and resistant capabilities of marine bacteria isolated from Niger Delta, Nigeria on petroleum pollutants and heavy metals. *Journal of Advances in Biology and Biotechnology*, 20 (1): 1 -17.

Uba, B. O., Okoye, E. L., Dokubo, C.U., Azuanichie, T. and Nworah, O.M. (2018b). Biostimulatory effect of organic and inorganic nutrients on soil biological indicators in diesel contaminated soil. *Journal of Bioscience and Biotechnology,* 3(6): 121 – 135.

Uba, B. O., Chukwura, E. I., Okoye, E. L., Umebosi, A.A., Agbapulonwu, U. F., Muogbo, O. C., Okoye, C. L., Oranta, L.O., Odunukwe, A.M., Ndurue, C. P. and Ehirim, O. S. (2018c). Biofilm and biosurfactant mediated aromatic hydrocarbons degradation by marine bacteria isolated from contaminated marine environments of Niger Delta. *Journal of Applied Life Sciences International,* 19 (4): 1 -17.

Uba, B.O. (2019a). Aromatic hydrocarbons degradation and plasmid profile of marine bacterial isolates obtained from petroleum contaminated marine environments of Niger Delta, Nigeria. *Microbiology Research Journal International*, 27 (1): 1 – 20.

Uba, B.O. (2019b). Effects of aromatic hydrocarbons and marine water from Niger Delta on the *β* – galactosidase activity of mutant *Escherichia coli*. *Archives of Current Research International*, 16 (3): 1 – 16.

Uba, B.O. (2019c). Phylogenetic framework and metabolic genes expression analysis of bacteria isolated from contaminated marine environments of Niger Delta. *Annual Research & Review in Biology,* 30 (5): 1 – 16.

Uba, B. O., Okoye, E. L., Anyaeji, O.J. and Ogbonnaya, O.C. (2019a). Antagonistic Potentials of actinomycetes isolated from coastal area of Niger Delta against *Citrus sinensis* (Sweet Orange) and *Lycopersicum esculentum* (Tomato) fungal pathogens. *Research and Reviews: A Journal of Biotechnology*, 8 (3): 4 – 15.

Uba, B.O., Akunna, M.C., Okemadu, O. C. and Umeh, C. J. (2019b). Kinetics of Biodegradation of total petroleum hydrocarbon in diesel contaminated soil as mediated by organic and inorganic nutrients. *Animal Research International*, 16 (2): 3295 – 3307.

Uba, B. O., Chukwura, E. I., Okoye, E. L., Ubani, O., Chude, C.O. and Akabueze, U. C. (2019c). *In vitro* degradation and reduction of aromatic hydrocarbons by marine bacteria isolated from contaminated marine environments of Niger Delta. *Advances in Research,* 18 (3): 1 - 17.

Uba, B.O., Okoye, E.L., Ebodi-Henry, J.N. and Okoye, W.K. (2019d). Organic and inorganic nutrients mediated enhanced bioremediation of diesel contaminated soil. *Tropical Journal of Applied Natural Sciences,* 2 (3): 39-51.

Uba, B.O., Akunna, M.C., Okemadu, O. C. and Umeh, C. J. (2019e). Kinetics of Biodegradation of total petroleum hydrocarbon in diesel contaminated soil as mediated by organic and inorganic nutrients. *Animal Research International*, 16 (2): 3295 – 3307.

Uba, B.O., Okoye, E.L., Chude, C.O. and Ogamba, J.O. (2020a). Assessment of the toxicity potentials of spent laptop battery wastes on essential soil microbes and plant bioindicators. *Asian Journal of Biology*, 9(2): 33 – 46. https://doi.org/10.9734/AJOB/2020/v9i230085.

Uba, B.O., Okoye, E.L., Nweke, B.G. and Ibeneme, C.P. (2020b). Evaluation of the ecotoxicity potentials of e-waste using *Selenastrum capricornutum* (microalga), *Eisenia fetida* (earth worm) and *Allium cepa* (onion bulb) as bioindicators. *Asian Journal of Biotechnology and Genetic Engineering,* 3(2): 20 – 31. https://journalajbge.com/index.php/AJBGE/article/view/24.

Uba, B.O., Egbujor, J.C. and Umeh, O.R. (2020c). *Selenastrum capricornutum* Prinz, *Zea mays* L. and *Phaseolus vulgaris* L. biomonitors: Natural monitors of spent phone battery toxicity. *Asian Journal of Advanced Research and Reports,* 13 (1): 31 – 41. https://doi.org/10.9734/AJARR/2020/v13i130300.

Uba, B.O., Okonkwo, C.J. and Umeh, O.R. (2020d). Experimental assessment of the toxicity effects of phone battery wastes on aquatic and terrestrial bioindicators. *Asian Journal of Biochemistry, Genetics and Molecular Biology*, 5(1): 17 – 27. https://doi.org/10.9734/AJBGMB/2020/v5i130117.

Uba, B. O., Udeh, C.A., Nduneri, C. F. and Akaun, I. P. (2020e). Potentials of carrot (*Daucus carota*) and cocoyam (*Colocasia esculenta*) peels as suitable mycological culture media. *Research & Reviews: A Journal of Life Sciences*, 10 (3): 22 – 29.

Uba, B. O., Chukwura, E. I., Iheukwumere, I.H., Okeke, J.J. and Akaun, I.P. (2020f). Evaluation of marine waste water and aromatic hydrocarbons toxicity using a battery of assays. *Research & Reviews: A Journal of Toxicology,* 10 (2): 1 – 13.

Uba, B. O., Obidike, K.N., Dokubo, C.U. and Nnaodi, I.D. (2020g). Bioelectricity generation using marine sediment and cow dung. *EC Microbiology*, 16 (10): 1 – 12.

Uba, B. O., Chukwura, E. I., Okoye, E. L., Ubani, O. and Odibo, F.J.C. (2021a). Toxicological evaluation of aromatic hydrocarbons using toxi-chromo test and mice model. *Indian Journal of Ecology,* 48 (5): 1533 – 1541. https://indianecologicalsociety.com/wp-content/themes/ecology/fullpdfs/1635504109.pdf.

Uba, B. O., Chukwura, E. I., Okoye, E. L., Emmy-Egbe, I. O. and Ubani, O. (2021b). Assessment of Toxicity of Marine Sediment and Aromatic Hydrocarbon Samples using Marine Algal Toxicity and Phytotoxicity Tests. *Indian Journal of Environmental Protection*, 41 (2): 123

Uba, B. O. and Anidu, F. N. (2023). Evaluation of the characterization and heavy metals remediation potential of biosurfactant produced by *Aeromonas hydrophila* S62A. *Archives of Agriculture and Environmental Science*, 8 (2):116 – 124.

Uba, B. O. and Obiefuna, G. O. (2023). Aerobically enhanced nanobioremediation of diesel oil contaminated soil and water using mycosynthesized silver nanoparticle as biostimulating agent. *Science World Journal* 18 (1): 75 – 82. https://scienceworldjournal.org/article/view/23510.

Uba, B.O., Okoye, E.L., Anyichie, J.C., Dokubo, C.U. and Ugwuoji, E.T. (2024). Synthesis, characterization and application of biogenic silver nanoparticles as antibacterial and antifungal agents. *Journal of Advances in Microbiology* 24 (3): 65 – 78. https://doi.org/10.9734/JAMB/2024/v24i3809.

Uba, B .O., Alfred, P. N., Ukpai, E. G., Ike, V. E. & Chikwendu, J. C. (2025). Diversity Of the Bacterial Communities Of Three Selected Streams In Anambra State, Nigeria. *Open Journals of Environmental Research*, 6 (2): 59 – 72. DOI: https://doi.org/10.52417/ojer.v6i2.453.

Ubani, O., Obiefuna, G.O., Uba, B.O., Dokubo, C.U., Mere, C. A. and Akaun, I.P. (2024). Kinetic modelling and half-life study on bioremediation of diesel oil contaminated soil and water using nano - remediation strategy: kinetic modelling and half-life study on bioremediation of diesel oil. *Multidisciplinary Science Journal* **7**: e2025182. https://doi.org/10.31893/multiscience.2025182.

Ubani, O., Uba, B. O., Modise, S. J., Egurefa, S. O., Orji, M. U. and Dokubo, C. U. (2025). A characterization and evaluation of the ecotoxicity of petroleum refinery effluents using a battery of bioassays. *Multidisciplinary Science Journal* 8 (3): 2026159. https://doi.org/10.31893/multiscience.2026159

Umeh, O.R., Chukwura, E.I., Ibo, E.M. and Uba, B.O. (2020). Evaluation of physicochemical, bacteriological and parasitological quality of selected well water samples in Awka and its environment, Anambra State, Nigeria. *Archives of Agriculture and Environmental Science* 5 (2): 73 – 88. https://doi.org/10.26832/24566632.2020.050201.

Umeh, O.R., Chukwura, E.I., Okoye, E.L., Ibo, E.M., Egwuatu, P. I. and Uba, B.O. (2021). Phytochemical Screening and Antibacterial Evaluation of Conventional Antibiotics, Garlic and Ginger on Isolates from Fish Pond Water Samples in Awka, Anambra State, Nigeria. *Journal of Pharmaceutical Research International* 33(30B): 118-132. https://doi.org/10.9734/jpri/2021/v33i30B31646

Unnisa, S.A. and Bi, S.Z. (2018). *Carica papaya* seeds effectiveness as coagulant and solar disinfection in removal of turbidity and coliforms. *Applied Water Science* 8:149.

World Health Organization (WHO) (2008). Safer water, better health: costs, benefits and sustainability of interventions to protect and promote health. World Health Organization, Geneva, Switzerland.

WHO (World Health Organization) and UNICEF, (2014). Progress on Drinking Water and Sanitation: 2014 World Health Organization and United Nation Children Fund (WHO and UNICEF) (2014). Update Geneva: WHO and UNICEF.

Yah, C. S. and Simate, G. S. (2015). Nanoparticles as potential new generation broad spectrum antimicrobial agents. *Daru*, 23 (1): 43.

Zekić, E., Vuković, Z. and Halkijević, I. (2018). Application of nanotechnology in wastewater treatment. *GRAĐEVINAR,* 70 (4): 315 – 323.

Zhang, C.L., Jiang, H.S., Gu, S.P., Zhou, X.H., Lu, Z.W., Kang, X.H., Yin, L. and Huang, J. (2019). Combination analysis of the physiology and transcriptome provides insights into the mechanism of silver nanoparticles phytotoxicity. *Environmental Pollution*, 252: 1539 - 1549.

---

[i] *Thanks for publishing with us*.