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Comparative toxicity of spent mobile phone batteries (Samsung and Tecno) on *Nitrobacter* sp

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Abstract: *This research was designed to evaluate the spent mobile phone batteries (Samsung and Tecno) concentration and the duration of exposure that could cause potential toxicity effect on the organism Nitrobacter sp. Winogradsky medium were used for the isolation of bacteria test species. Standard toxicity procedures were applied using mobile phone batteries, Samsung and Tecno prepared at concentrations of 0%, 6.25%, 12.5%, 25%, 50% and 75%, tested for exposure period of 0h, 4h, 8h, 12h and 24h. The median lethal concentration (LC_{50}) of the batteries used decreased in the following order: (noting the lower the LC_{50} the more toxic the toxicant); Samsung phone battery in fresh water (44.32%) > Samsung phone battery in marine water (44.75%) > Tecno phone battery in marine water (45.23%) > Samsung phone battery in brackish water (45.66%) > Tecno phone battery in brackish water (47.36%) > Tecno phone battery in fresh water (48.20%).Conclusively, Samsung phone battery in fresh water (LC_{50} = 44.32%) is the most toxic; having the lowest LC_{50} while Tecno phone battery in fresh water (LC_{50}= 48.20%) has the lowest toxicity strength. This result shows that Samsung battery elicit mortality rate of Nitrobacter than Tecno phone battery.*

***Keywords**: Toxicity, median lethal concentration (LC_{50}), Mobile Phone batteries, Samsung and Tecno, Nitrobacter* sp.

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I. Introduction

An electric battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices (Chung et al, 2002). Primary batteries are the most common household battery. These batteries automatically convert chemical energy into electrical energy. This kind of battery cannot be recharged and are thrown away straight after use. They are commonly known as alkaline batteries, contain zinc and manganese chemistry, and are often used in torches, toys, smoke detectors, watches, calculators, hearing aids, radios and remote controls. Secondary batteries are rechargeable and can be used repeatedly. These batteries are usually nickel cadmium, nickel metal hydride or lithium ion. Secondary batteries are commonly found in cordless phones, cordless drills, mobile phones (Samsung and Tecno batteries), laptops and computers, shavers, digital cameras, video cameras and house alarms. Although rechargeable, secondary batteries may need to be recycled when they no longer hold a charge. Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to battery banks the size of rooms that provide standby power for telephone exchanges and computer data centers (Yamabe, 2015). Major components of the mobile phone: mobile phones are complicated gadgets capable of processing millions of calculations per second. Their components each have their useful functions however also contribute to the waste problem created when disposing of these devices. Mostly, mobile phones comprise of a handset (includes: Printed Circuit Board (PCB), Liquid Crystal Display (LCD), Keypad, Antennae, Microphone, Casing), a battery and a charger. Printed Circuit Board (PCB): Circuitry made mostly of copper is soldered to the board with protective coatings and adhesives. The board is made of epoxy resin or fiber glass and generally coated with gold plating. Other precious metals and hazardous substances in the PCB are arsenic (in chips made from gallium arsenide), antimony, beryllium, brominated flame retardants, cadmium, lead (used in the solder that joins the parts), nickel, palladium, silver, tantalum and zinc. The lead and brominated flame retardants have the highest environmental impact due to their levels of toxicity and persistence in the environment. (Godshall, et al., 1982). Liquid Crystal Display: The LCD as the name suggests contains liquid crystals which are embedded between layers of glass for illumination with transistors for an electric charge. The liquid crystalline substances can contain toxic substances such as mercury. Foil display systems are now under development which would make LCD's much more environmentally friendly, especially in small products. Battery: Mobile phone batteries can contribute significantly to a device's environmental impact. Rechargeable batteries generate less waste than single-use batteries however, as with rechargeable batteries belonging to mobile phones, toxic components such as cadmium, nickel, zinc and copper can pose end of life hazards. Plastic Casing: The plastic used to case the phone together is usually polycarbonate (PC), acrylonitrile butadiene styrene (ABS), or a combination of the two. These plastics are difficult to recycle through a normal mixed plastic process as they often contain brominated flame retardants, to reduce the risk of fire. Brominated flame retardants are damaging to the environment and human health as they are persistent, bioaccumulative and toxic. Other Components: Antenna, Speaker, Microphone, Keypad, and Accessories most other components of the handset are very small however these too contain heavy metals and hazardous materials on microorganisms. Mobile phone accessories can also contribute to the toxic waste problem. (Nazri and Pistoia, 2004).

Nitrobacter is a genus of mostly rod-shaped, gram-negative, and chemoautotrophic bacteria. They play an important role in the nitrogen cycle by oxidizing nitrite into nitrate in soil. Unlike plants, where electron transfer in photosynthesis provides the energy for carbon fixation, *Nitrobacter* uses energy from the oxidation of nitrite ions, NO_2^-, into nitrate ions, NO_3^-, to fulfill their energy needs. *Nitrobacter* fixes carbon dioxide via the Calvin cycle for their carbon requirements. Having optimum pH between 7.3 and 7.5, and will die in temperatures exceeding 49°C (degree celcius) or below 0°C. Notable species include, *Nitrobacter winogradsky, Nitrobacter alkalicus, Nitrobacter vulgaris,* and *Nitrobacter hamburgensis*. Toxicity is the degree to which a substance can damage an organism. Toxicity can refer to the effect on a whole organism, such as an animal, bacterium, or plant, as well as the effect on a substructure of the organism, such as a cell (cytotoxicity) or an organ such as the liver (hepatotoxicity). A central concept of toxicology is that effects are dose-dependent; even water can lead to water intoxication when taken in too high a dose, whereas for even a very toxic substance such as snake venom there is a dose below which there is no detectable toxic effect. Toxicity is species-specific, making cross-species analysis problematic. Newer paradigms and metrics are evolving to bypass animal testing, while maintaining the concept of toxicity endpoints (Syzdek, *et al.*, 2007).

The overall aim of this research is to find out if these batteries pose any toxic effect on *Nitrobacter* species.

II. Materials and Methods

Sample Collection/Study Area

Fresh water sample was collected from Asarama stream, Asarama town in Andoni L.G.A, Rivers state with a two (2) litre sterile plastic container, marine water was collected from Bonny River in Bonny, Rivers State with a two (2) litre sterile plastic container, also, brackish water was collected from Eagle Island River in Port Harcourt Nigeria with a two (2) litre sterile plastic container. These were used within one hour of collection.

Microbiological Analysis

Preparation of Media

Winogradsky Agar (modified) medium composition: Agar agar 15.0g/l, King agar B base 3g/l, KNO_2 0.1g/l, Na_2CO_3 0.5g/l, $FeSO_4.7H_2O$ 0.4g/l, NaCl 0.5g/l, Distilled water 1000ml. Winogradsky Agar media were prepared and autoclaved at 121ºC for 15minutes after which it was allowed to reduce to about 40c and the medium was poured on the Petri-dishes. Then, the medium was allowed to solidify before progress to the hot air oven to dry the moisture. The Petri-dishes were the inoculated with the fresh water, marine water and brackish water was inoculated aerobically for 4days at room temperature (30± 2ºc), grayish, mucoid, flat colonies revealed pear-shaped, and Gram negative of *Nitrobacter* (Odokuma and Nrior, 2015).

Toxicity Test

Preparation of the toxicant

Spent Samsung and Tecno batteries were aseptically clipped open and immediately submerged in freshwater, brackish and marine water separately. The toxicant were prepared by setting up six test tubes aseptically covered with cotton wool. The test was carried out in six separate test tubes containing appropriate filtered water (fresh, marine and brackish water from the habitat of the organism separately). In each of the test tubes, the five toxicant concentrations (6.25%, 12.5%, 25%, 50% and 75%) were added separately. The test tubes were the covered with cotton wool, the control consists of fresh, marine and brackish water from the habitat of the organism.

Test procedure for *Nitrobacter* specie from freshwater, brackish and marine water About 1ml of the test organism was added to separate toxicant concentrations in test tubes containing (6.25%, 12.5%, 25%, 50%, 75% and control respectively), and was plated out immediately after inoculation on winogradsky agar plate. This is known as zero-hour count plating. And then was incubated at room temperature (28± 2ºc). Aliquot (0.1ml) of each of the concentrations of the effluent was then plated out after 4hours, 8hours, 12hours and 24hours on winogradsky agar and was incubated for 42hours. After which the plate were counted.

Percentage log survival of the bacteria (*Nitrobacter* sp.) isolates in mobile phone batteries. The percentage log survival of the *Nitrobacter* isolates in the mobile phone batteries effluent used in the study was calculated using the formula adopted from Williams and Johnson(1981) ; Odokuma and Nrior (2015). The percentage log survival of the bacteria isolates in the effluent was calculated by obtaining the log of the count in toxicant concentration, dividing by the log of the count in the zero toxicant concentration and multiplying by 100. Thus:

$$\text{Percentage (\%) log survival} = \frac{\text{LogC}}{\text{Logc}} \times 100$$

where:
LogC=log of the count in each toxicant concentration
Logc=log of count in the control (zero toxicant concentration).

Percentage (%) log mortality = 100 - % log survival

Percentage mortality bacteria from fresh, marine and brackish water

This study was carried out to assess the probable toxic effect, cell batteries could have in fresh, marine and brackish water (aquatic environment). The formula for calculation of percentage mortality was adopted from APHA (1992), Nrior and Obire (2015). And the percentage mortality was done by dividing the percentage (%) log control by the percentage (%) log survival-control.
%Mortality = Zero toxicant Concentration - % log survival.

III. Results and Discussion

Toxicity test was carried out on *Nitrobacter* specie using two toxicant (Samsung and Tecno batteries) also the median lethal concentration (LC_{50}) were also calculated. The lethal toxicity result of mobile phone batteries (Samsung and Tecno) was done by calculating the log survival of the count in each toxicant concentration divided by the log of the count in each toxicant concentration and multiply by 100. The percentage (%) log survival of the test organism *Nitrobacter* sp. to the toxicants spent Samsung and Tecno phone batteries were shown in Fig. 1-6. The results obtained during this research revealed that certain substances in lithium battery used to power mobile phones are relatively toxic in certain concentrations to *Nitrobacter* species of bacteria. Similar observations have been reported (Wang, 1984). A good increase in the loss of *Nitrobacter* with increasing exposure time was observed in the media as the concentration of the battery cells are increase.

During this research Samsung mobile batter proves to be more lethal to *Nitrobacter* than the Tecno battery and the longer these organisms are being exposed to these toxicants the more lethal it becomes to them as shown in the results obtained.

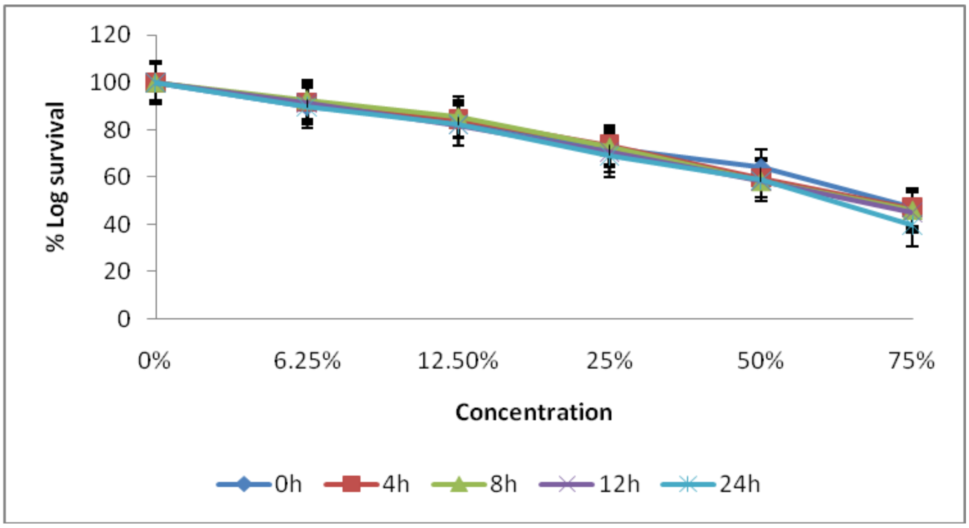

Fig. 1: Lethal toxicity of Samsung mobile phone battery on *Nitrobacter* sp. in fresh water.

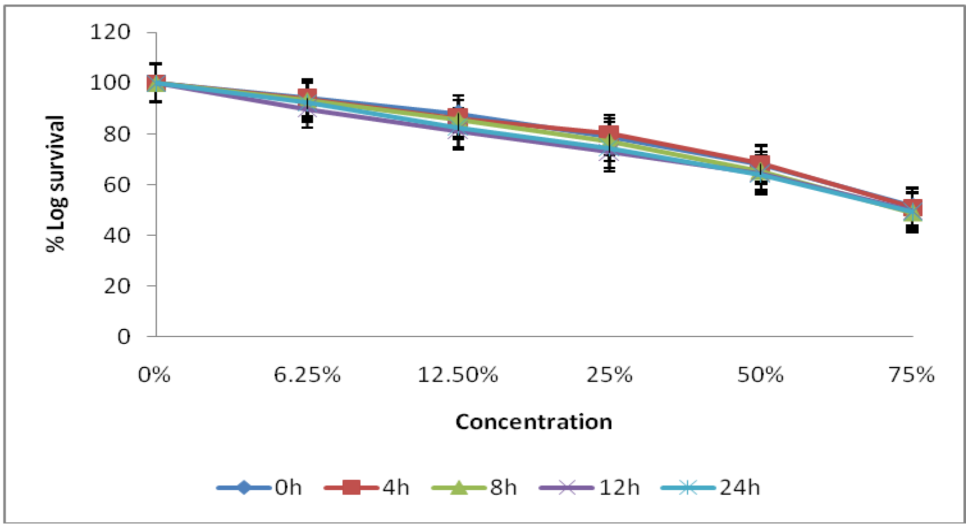

Fig. 2: Lethal toxicity of Tecno mobile phone battery on *Nitrobacter* sp. in fresh water.

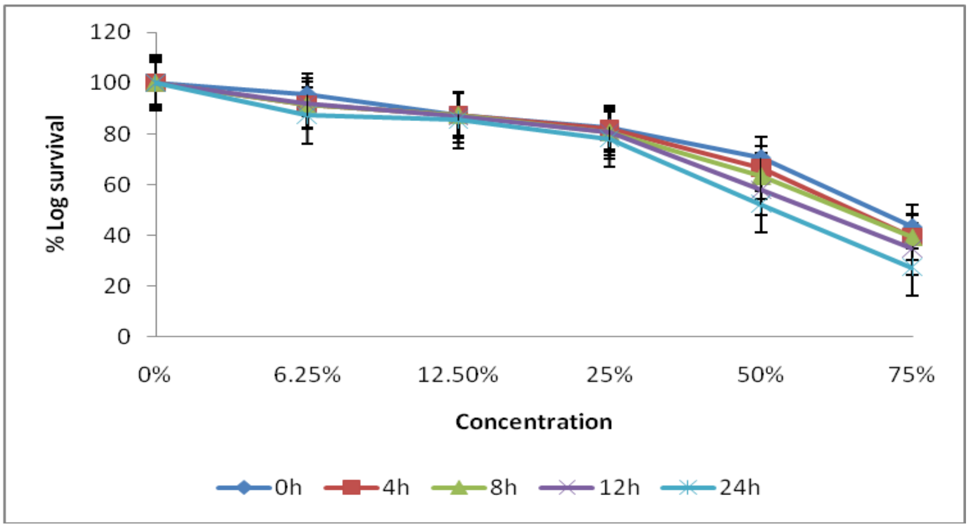

Fig. 3: Lethal toxicity of Samsung mobile phone battery on *Nitrobacter* sp. in Marine water

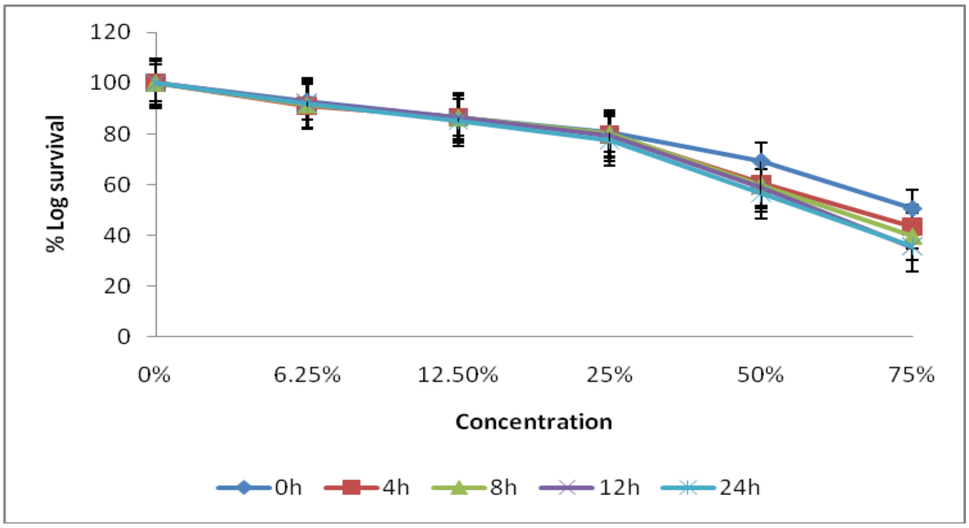

Fig. 4: Lethal toxicity of Tecno mobile phone battery on *Nitrobacter* sp. in Marine water

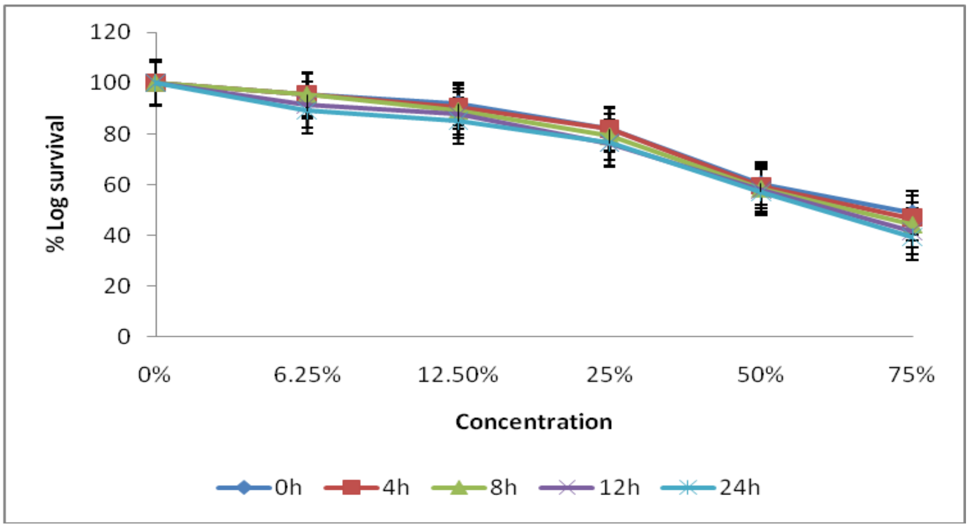

Fig. 5: Lethal toxicity of Samsung mobile phone battery on *Nitrobacter* sp. in Brackish water

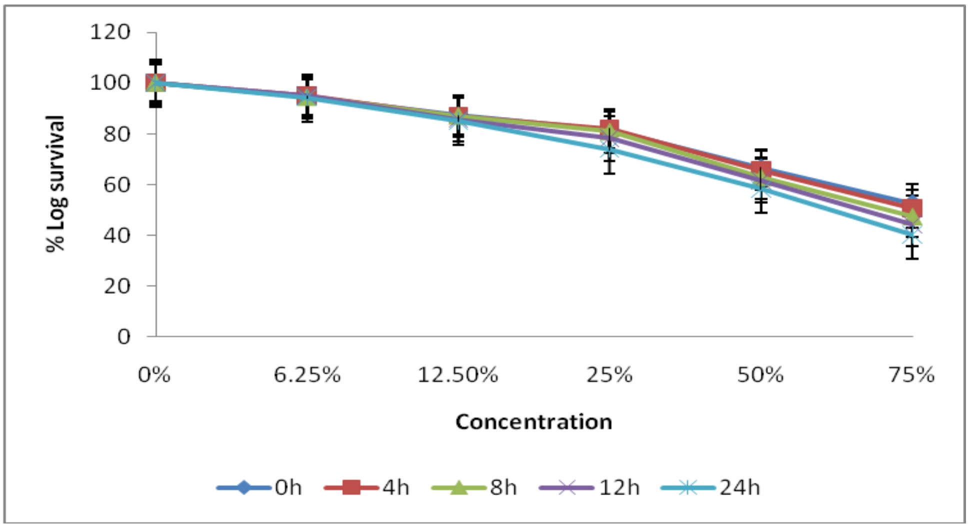

Fig. 6: Lethal toxicity of Tecno mobile phone battery on *Nitrobacter* sp. in Brackish water

Toxicity seems to be altered or affected by the salinity of the medium, as Samsung battery shows to be more toxic in fresh water with a lethal concentration of 44.32% than it is in marine water and brackish water with lethal concentration of 44.75% and 45.66% respectively. While the Tecno battery is more toxic in marine with lethal concentration of 45.23% than it is in fresh and brackish that has lethal concentration of 48.20% and 47.36% respectively. This may be due to chemical reactions between the compound in the lithium battery and the salts found in these waters. This marked decrease in the number of *Nitrobacter* sp. as the mobile battery toxicant is increase, suggests that components present in this lithium battery is highly toxic to *Nitrobacter* and may interfere with the nitrogen cycle if this battery are improperly disposed in the environment.

Table 1: Calculating Median Lethal Concentration (LC_{50}) from Percentage (%) log mortality of *Nitrobacter* sp. on Samsung battery in Fresh water

Dose	% mortality	Mean % mortality	Dose diff.	∑ of dose diff. × mean % mortality
0	0	-	-	-
6.25%	44.56	8.912	6.25	55.7
12.5%	81.57	16.314	6.25	101.962
25%	141.65	28.33	18.75	531.187
50%	200.78	40.156	25	1003.9
75%	274.99	54.998	25	1374.95
				3067.699

$$LC_{50} = Lc_{100} - \frac{\sum \text{dose diff.} \times \text{mean \% mortality}}{\text{\% control}}$$

$$LC_{50} = 75 - \frac{3067.699}{100}$$

LC_{50} = 75 – 30.676 = 44.32
LC_{50} = 44.32%

Table 2: Calculating Median Lethal Concentration (LC_{50}) from Percentage (%) mortality of Tecno battery on *Nitrobacter* sp. in Fresh water

Dose	% mortality	Mean % mortality	Dose diff.	∑ of dose diff. × mean % mortality
0	0	-	-	-
6.25%	36.43	7.286	6.25	45.537
12.5%	76.58	15.316	6.25	95.725
25%	117.18	23.436	18.75	439.425
50%	170.08	34.016	25	850.4
75%	249.67	49.934	25	1248.35
				2679.437

$$LC_{50} = Lc_{100} - \frac{\sum \text{dose diff.} \times \text{mean \% mortality}}{\text{\% control}}$$
$$LC_{50} = 75 - \frac{2979.437}{100}$$
LC_{50} = 75 – 26.794 = 48.20
LC_{50} = 48.20%

Table 3: Calculating Median Lethal Concentration (LC_{50}) from Percentage (%) log mortality of Samsung battery on *Nitrobacter* sp. in Marine water

Dose	% mortality	Mean % mortality	Dose diff.	∑ of dose diff. × mean % mortality
0	0	-	-	-
6.25%	42.53	8.506	6.25	53.162
12.5%	65.35	13.07	6.25	81.687
25%	96.9	19.38	18.75	363.375
50%	189.37	37.874	25	946.85
75%	315.86	63.172	25	1579.3
				3024.374

$$LC_{50} = Lc_{100} - \frac{\sum \text{dose diff.} \times \text{mean \% mortality}}{\text{\% control}}$$
$$LC_{50} = 75 - \frac{3024.374}{100}$$
LC_{50} = 75 – 30.243 = 44.75
LC_{50} = 44.75%

Table 4: Calculating Median Lethal Concentration (LC_{50}) from Percentage (%) log mortality of Tecno battery on *Nitrobacter* sp. in Marine water

Dose	% mortality	Mean % mortality	Dose diff.	∑ of dose diff. × mean % mortality
0	0	-	-	-
6.25%	41.02	8.204	6.25	51.275
12.5%	69.35	13.87	6.25	86.687
25%	103.47	20.694	18.75	388.012
50%	194.97	38.994	25	974.85
75%	295.08	59.016	25	1475.4
				2976.224

$$LC_{50} = Lc_{100} - \frac{\sum \text{dose diff.} \times \text{mean \% mortality}}{\text{\% control}}$$
$$LC_{50} = 75 - \frac{2976.224}{100}$$
LC_{50} = 75 – 29.762 = 45.23
LC_{50} = 45.23%

Table 5: Calculating Median Lethal Concentration (LC_{50}) from Percentage (%) mortality of Samsung battery on *Nitrobacter* sp. in Brackish water

Dose	% mortality	Mean % mortality	Dose diff.	∑ of dose diff. × mean % mortality
0	0	-	-	-
6.25%	33.58	6.716	6.25	41.975
12.5%	55.99	11.198	6.25	69.987
25%	104.56	20.912	18.75	392.1
50%	206.94	41.388	25	1034.7
75%	278.92	55.784	25	1394.6
				2933.362

$LC_{50} = Lc_{100}$ - <u>∑ dose diff. × mean % mortality</u>

% control

$LC_{50} = 75 - \frac{2933.362}{100}$

$LC_{50} = 75 - 29.333 = 45.66$

$LC_{50} = 45.66\%$

Table 6: Calculating Median Lethal Concentration (LC_{50}) from Percentage (%) log mortality of Tecno battery on *Nitrobacter* sp. in Brackish water

Dose	% mortality	Mean % mortality	Dose diff.	∑ of dose diff. × mean % mortality
0	0	-	-	-
6.25%	27.27	5.454	6.25	34.087
12.5%	68.2	13.64	6.25	85.25
25%	103.54	20.708	18.75	388.275
50%	183.3	36.66	25	916.5
75%	267.97	53.594	25	1339.85
				2763.962

$LC_{50} = Lc_{100} - \frac{\sum \text{dose diff.} \times \text{mean \% mortality}}{\text{\% control}}$

$LC_{50} = 75 - \frac{2763.962}{100}$

$LC_{50} = 75 - 27.639 = 47.36$

$LC_{50} = 47.36\%$

This study also revealed that, Samsung and Tecno mobile phone batteries could poses great toxicity problem to the organism (*Nitrobacter* sp.) in Asarama - Andoni stream [freshwater], Bonny sea [marine water] and Eagle Island river [brackish water] in Rivers State, Nigeria. Toxicity assessment of mobile phone batteries (Samsung and Tecno) using the static with renewal option for acute toxicity at the concentration 6.25%, 12.5%, 25%, 50%, 75% for *Nitrobacter* sp. 0h, 4h, 8h, 12h and 24h were employed. The test organism used were *Nitrobacter* sp. in freshwater, brackish water and marine water.

Nitrobacter sp. mortality of the test organism expressed as Median Lethal Concentration (LC_{50}) were used as indices to monitor toxicity (Odokuma and Nrior, 2015). The sensitivity of the bacterium *Nitrobacter* sp. to the toxicity of the different mixture of mobile phone batteries (Samsung and Tecno) with the different water (freshwater, marine water and brackish water) samples decreased in the following order (noting the lower the LC_{50} the more toxic the toxicant); Samsung – freshwater (44.32%) > Samsung – marine water (44.75%) > Tecno - marine water (44.23%) > Samsung –brackish water (45.66%) > Tecno – brackish water (47.36%) > Tecno – freshwater (48.20%) (Table 1-6, Fig. 7)

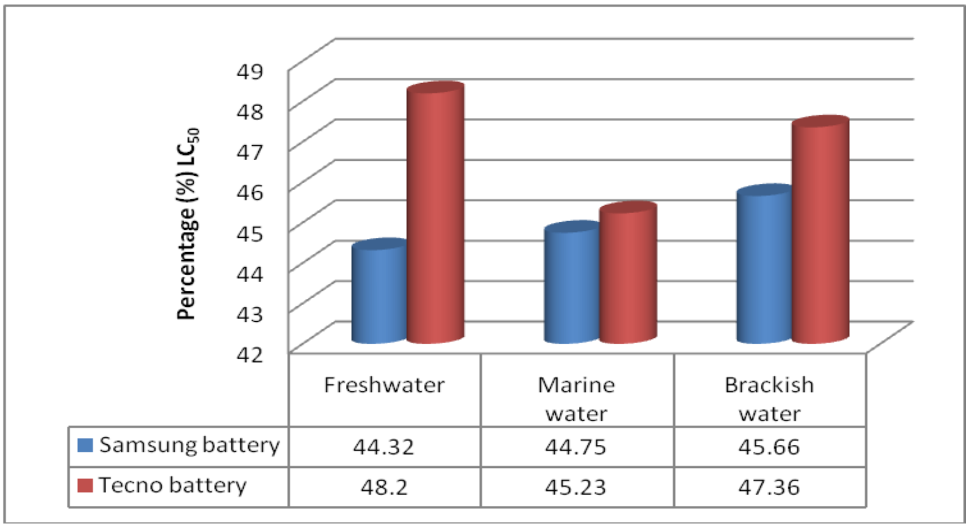

Figure 7: Summary of Median Lethal Concentration (LC50) of Moblie Phone batteries (Samung and Tecno) on *Nitrobacter* sp. in freshwater, marine and brackish water

The response of *Nitrobacter* sp. from (freshwater, marine water and brackish water) analyzed statistically using Analysis of Variance (ANOVA) to test significant difference in their response to the Samsung and Tecno batteries at 6.25% probability level. The result revealed that at 6.25% probability level, there was a significant difference between the susceptibility of Nitrobacter in freshwater, marine and brackish water.

However, there was no significant difference between the susceptibility of *Nitrobacter* sp. isolated from freshwater, marine and brackish water to the toxicity of the mobile phone batteries (Samsung and Tecno).

IV. Conclusion and Recommendation

The result revealed that, the hazardous chemicals from these batteries can cause environmental contamination affecting *Nitrobacter* spp. They can also cause a variety of serious health issues in humans if released into the environment. The major characteristic which cause these substances to be more dangerous are their persistence and bioaccumulation. Mobile phone batteries (Samsung and Tecno) are very toxic to *Nitrobacter* spp. which is used as an environmental pollution biomarker/monitor; hence its concentration in the aquatic environment (Fresh, Marine and Brackish water) should be strictly monitored.
It is also recommended that chemicals such as Samsung and Tecno batteries should not be discharged directly into a water body.

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