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Ecotoxicological Assessment of Leachate from Municipal Solid Waste Dumpsites

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Abstract

The ecotoxicological effects of leachates from dumpsite have become a major problem. Leachates arising from waste dumpsites are transported by surface runoff or infiltration through the soil and become bioavailable in the ecosystem. The ecotoxicological assessment of leachates from 6 dumpsite in Yenagoa Metropolis were investigated against adult and fingerlings of Clarias gariepinus (African catfish). Ecotoxicological activities (LC50 values) were reported for the following stations; Akenpai (124.57 ppm), and Etegwe stations (95.38 ppm), as well as Opolo (157.95 ppm), and Kpansia Markets (123.82 ppm). In addition, leachates of the two stations from the central dumpsite (CDS), were the most active (CDS 1; 60.97 ppm, and CDS 2; 76.65 ppm). Notwithstanding, the order of toxicological activities of the leachates were reported as; CDS 1>CDS2>Etegwe>Akenpai>Kpansia market>Opolo Market. These results confirm the toxicity of leachates from the dumpsites. In addition, we recommend that government, regulators and all stakeholders should enact policies to treat, reduce, recycle and reduce waste stream in order to mitigate the adverse effects on the ecosystem.

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Introduction

The urbanization, industrialization and commercialization, has had its effects to the significant upswing of waste streams [1, 2, 3]. In addition, most developing country are challenged by poor funding, legislation and sensitization of the populace on waste reduction, reuse and recycling [4]. Due to poor or inadequate waste management policies in most developing countries, the application of landfills system have become a threat to biodiversity [4].

Huge streams of untreated and unsegregated waste are seen littered across most metropolis with potential infringement of the ecosystem. These wastes undergoes environmental transformation infringing on vital components of the ecosystem, including soil, are and water are most obliged media of environmental pollution. For instance leachates from dumpsites infiltrate to pollute groundwater or swept by runoff thereby causing surface water contamination. Toxicants from leachate have been found to have attendant adverse effect on biodiversity especially groundwater resource and aquatic biota [3, 5, 6].

Yenagoa Metropolis is the capital city of Bayelsa State, which is a deltaic wetland that forms part of the Niger Delta Region. Its climate is humid tropical, with high precipitation that favour the transformation and mobility of leachate contaminants [4]. Heavy metals are major toxic component in waste leachate, in contaminated soil can enrich the ecosystem, and accumulated in food chain complexes with potential adverse effects [7].

Heavy metals like Cadmium can cause acute systemic impairment of the heart, brain, and kidney [7]. Heavy metal like iron from the Niger Delta Region have been reported for fish kill [8], inhibit plant growth and metabolic processes like; ascorbic acid and chlorophyll levels of [9]. Consequently, the Ecotoxicological assessment of leachate from municipal solid waste dumpsites have become necessary.

Materials and Method

Study Area

Yenagoa is the capital city of Bayelsa State which is located on the Southernmost (South-South) part of the Nigerian map. Bayelsa state is a wetland and Tropical rain forest and several networks of creeklets, creeks and Rivers that empties into a major Deltaic Tributary called River Nun. It is characterized by dry and dusty with higher temperature and ranges from November to March. The wet season which is relatively cooler with relative humidity of 80 - 90%, and temperature of 25°C - 28°C has annual rainfall of 2000mm and 4000mm inland and coastwards respectively.

Sampling

Leachate were collected from the 6 stations of the MSW dumpsites plastic container and transported to the laboratory for the toxicological bioassay. The toxicity bioassay was a two-phased 96 hour static non-renewal test, involving the rapid screening and final screening phase as described by several authors [8, 9, 10, 11].

Test Organisms

Fingerling and adult catfish (*Claias gariepinus*), were obtained from homestead fish pond and transported to the laboratory for acclimatization. The fingerling and the matured fish were separated in aerated aquarium and fed and acclimatized to laboratory condition.

Toxicity Bioassay (Rapid and Final Screening)

The toxicity bioassay was a two-phased screening termed rapid and final screening. The rapid screening is a screening phase that determine the range of activity (ROA), of the leachate against the test organism. In this phase concentrations of 1000 ppm and 500 ppm were used to screen the test organism for total (100%) mortality in a 96 hours static non-renewal bioassay. Furthermore, the bioassay which demonstrated total (100%) mortality at concentration of 500 ppm within 96 hours, during the rapid screening phase is only subjected to the final screening. Implying that lesser toxic bioassay whose total mortality rate exceeds 500ppm are not sanctioned for the final screening. This screening phase involves the bioassay that showed efficacy with minimal lethal concentration of 500 ppm (i.e $LC100 \leq 500$ ppm). Varying concentrations lower than 500ppm in descending order were used to for the further screening until the minimal lethal concentration was determined.

Statistical Analysis

All data emerging from the study were sampled in triplicates, and subjected to statistical analysis based on version 20 of SPSS. Meanwhile, analysis of Variance (ANOVA) was used for mean separation, while Duncan multiple range Post Hoc was used to detect the significance ($p=0.05$). Also 2015 version of Microsoft excel package was used to compute mean values and plot graph. The LC_{50} value was determined based on the equation of the logarithm in the dose-response curve.

Result and Discussion

Table 1 presents the results of general physicochemical properties of the leachates. The leachate from Akenpai station had pH of 5.87 and turbidity of 94.33NTU, also the leachate indicated BOD5 and COD level of 75.33 and 95.67 mg/l respectively. The physicochemical properties of leachate from Etegwe station had pH of 5.57 and turbidity of 211.00NTU, also the BOD5 and COD level of the leachate were 81.67 and 111.00 mg/l respectively. The physicochemical assessment of leachate from Opolo market station recorded pH of 6.33, turbidity of 182.33NTU, as well as BOD_5 and COD level of 61.33 and 84.33 mg/l respectively (Table 1). The physicochemical properties of leachate from Kpansia market station had pH value of 6.13 and turbidity of 198.00NTU, BOD5 of 53.00 mg/l and a COD level of 74.33 mg/l respectively (Table 1).

The physicochemical properties of leachate from the first station of the central dumpsite was more acidic with pH of 4.87 and turbidity of 285.67NTU, also BOD5 and COD level of 109.67 and 130.67 mg/l respectively (Table 1). The physicochemical properties of leachate from the second station of the central dumpsite indicated pH level of 5.20, turbidity of 232.67NTU, as well as BOD5 and COD levels of 93.00 and 124.00 mg/l respectively (Table 1).

Table 2 presents results of the rapid toxicity screening of fingerlings and adult catfish assayed against leachates from 6 dumpsite stations. Result of the all leachates bioassay against the fingerling indicated total mortalities (Table 1). Furthermore at concentrations of 500 and 1000ppm in less than 8 hours. On the other hand, the toxicity bioassay of leachates from all dumpsites against the adult catfish significantly ($p<0.05$) induced no mortalities at the already established concentrations (500 and 1000ppm), within 96 hours. Notwithstanding, sublethal effects against the adult fish were observed during the bioassay.

Meanwhile the negative control induced no mortality to both adult and fingerlings throughout the exposure of the bioassay at 500 and 1000ppm. On the other hand, the positive control significantly ($p<0.05$) induced total mortalities to both fingerling and adult fish at 500 and 1000ppm respectively. As such, the fingerling bioassay that induced mortalities at concentration ≤ 500ppm is further subjected to final screening, as opposed to the adult species that had no adverse effects at concentrations ≥1000ppm.

Table 3 presents the results of the final screening of leachates from the dumpsite stations, assayed against the fingerlings. Leachates from the

Table 1. Physicochemical properties of the leachates

	pH	Turbidity (NTU)	BOD5 (mg/l)	COD (mg/l)
Akenpai	5.87±0.15	94.33±4.04	75.33±1.15	95.67±4.16
Etegwe	5.57±0.11	211.00±2.00	81.67±2.08	111.00±8.54
Opolo	6.33±0.15	181.33±2.31	61.33±2.51	84.33±3.51
Kpansia	6.13±0.15	198.00±1.73	53.00±1.73	74.33±5.13
CDS 1	4.87±0.15	285.67±4.193	109.67±2.52	130.67±1.52
CDS 2	5.20±0.26	232.67±2.31	93.00±4.36	124.00±3.61

Data expressed as mean±standard deviation

Table 2. Result on Mortality Rate of the Rapid Screening Bioassay

Concentration (ppm)	Fingerlings (Mortality Rate %)		Adult Fish (Mortality Rate %)	
	500ppm	1000ppm	500ppm	1000ppm
Akenpai	100±0.00	100±0.00	0±0.00	0±0.00
Etegwe	100±0.00	100±0.00	0±0.00	0±0.00
Opolo	100±0.00	100±0.00	0±0.00	0±0.00
Kpansia	100±0.00	100±0.00	0±0.00	0±0.00
CDS 1	100±0.00	100±0.00	0±0.00	0±0.00
CDS 2	100±0.00	100±0.00	0±0.00	0±0.00
Positive control	100±0.00	100±0.00	100±0.00	1000±0.00
Negative control	0±0.00	0±0.00	0±0.00	0±0.00

Data expressed as mean±standard deviation

Table 3. Mortality Rate of the Final Screening Bioassay

Concentration (ppm)	Akenpai	Etegwe	Opolo	Kpansia	CDS 1	CDS 2
	0±0.00	0±0.00	0±0.00	0±0.00	0±0.00	0±0.00
25	0±0.00	0±0.00	0±0.00	0±0.00	0±0.00	0±0.00
50	0±0.00	16.67±5.77	0±0.00	0±0.00	26.67±5.77	23.33±5.77
75	13.33±5.77	16.67±5.77	0±0.00	0±0.00	50.00±10.00	43.33±5.77
100	16.67±5.77	33.33±5.77	3.33±5.77	0±0.00	70.00±10.00	53.33±11.55
125	26.67±5.77	56.67±11.54	16.67±5.77	13.33±5.77	83.33±5.77	83.33±5.77
150	50.00±0.00	70.0±10.00	36.67±5.77	26.67±5.77	100.00±0.00	86.67±11.54
175	70.00±10.00	100±0.00	56.67±5.77	63.33±11.54	100±0.00	100±0.00
200	100±0.00	100±0.00	80±0.00	83.33±5.77	100±0.00	100±0.00
225	100±0.00	100±0.00	100±0.00	100±0.00	100±0.00	100±0.00
250	100±0.00	100±0.00	100±0.00	100±0.00	100±0.00	100±0.00

Data expressed as mean±standard deviation

Akenpai station had No Observable Adverse Effect Level (NOAEL) at concentration of 50ppm, while Lowest Observable Adverse Effect Level (LOAEL) was induced at concentration of 75ppm with mortality rate of 13.33% ($p<0.05$). Meanwhile, the minimal lethal concentration (LC100) was indicated at concentration of 200ppm within exposure of 5 hours ($p<0.05$), with mortality time of 10 hours.

Table 3 presents the results of the final screening of leachates from the dumpsite stations, assayed against the fingerlings. Leachates from the Akenpai station had No Observable Adverse Effect Level (NOAEL) at concentration of 50ppm, while Lowest Observable Adverse Effect Level (LOAEL) was induced at concentration of 75ppm with mortality rate of 13.33% (Figure 1). Meanwhile, the minimal lethal concentration (LC_{100}) was indicated at concentration of 200ppm within exposure of 5 hours ($p<0.05$), with mortality time of 10 hours.

Furthermore, based on the dose-response curve statistical assessment of the leachate from the Akenpai station induced mortality with LC_{50} value of 124.57ppm (Figure 1). The physicochemical properties of leachate from Akenpai station had pH of 5.87 and turbidity of 94.33NTU, also the leachate indicated BOD5 and COD level of 75.33 and 95.67 mg/l respectively (Table 25). Table 3 presents the results of the final screening of leachates from the dumpsite stations, assayed against the fingerlings. Leachates from the Akenpai station had No Observable Adverse Effect Level (NOAEL) at concentration of 50ppm, while Lowest Observable Adverse Effect Level (LOAEL) was induced at concentration of 75ppm with mortality rate of 13.33% (Figure 1). Meanwhile, the minimal lethal concentration (LC_{100}) was indicated at concentration of 200ppm within exposure of 5 hours ($p<0.05$), with mortality time of 10 hours. Furthermore, based on the dose-response curve statistical assessment of the leachate from the Akenpai station induced mortality with LC_{50} value of 124.57ppm.

Results of the final screening of leachates from the dumpsite at Etegwe station, assayed against the fingerlings had NOAEL value at concentration of 25ppm (Table 3). However, LOAEL was induced at concentration of 50ppm with mortality rate of 16.67%. Meanwhile, the minimal lethal concentration (LC_{100}) was significantly ($p<0.05$) induced at concentration of 175ppm within exposure of 4 hours. Furthermore, based on the dose-response curve statistical assessment of the leachate from the Etegwe station induced mortality with LC_{50} value of 95.38ppm (Figure 2).

Leachates from the Opolo Market station, indicated NOAEL at concentration of 75ppm (Table 3). However, LOAEL was induced at concentration of 50ppm with mortality rate of 3.33%. Meanwhile, the minimal lethal concentration was reported at concentration of 225ppm, within exposure of 10 hours. Furthermore, leachate from the Opolo market had LC_{50} value of 157.95ppm as presented in Figure 3.

Furthermore, results of the toxicity bioassay from leachate in the Kpansia Market station against the fingerlings induced NOAEL at concentration of 100ppm (Table 3). Notwithstanding, the LOAEL was induced at concentration of 125ppm with mortality rate of 13.33%. Meanwhile, the minimal lethal concentration (LC_{100}) was significantly ($p<0.05$) induced at concentration of 225ppm within exposure of 7 hours. Furthermore, based on statistical assessment of the dose-response curve of the leachate from the Kpansia market station induced mortality with LC_{50} value of 123.82ppm (Figure 4).

In terms of mortality rate result of the toxicity bioassay from the first station of the central dumpsite (CDS 1) showed NOAEL at concentration of 25ppm (Table 3). However, the LOAEL was induced at concentration of 50ppm with mortality rate of 26.67%. In addition, the minimal lethal concentration (LC_{100}) was induced with significant difference ($p<0.05$) at concentration of 150ppm within exposure of 3 hours. Notwithstanding, based on the statistical dose-response assay, leachate from the first station of the central dumpsite demonstrated mortality with LC_{50} value of 67.97ppm (Figure 5).

Furthermore, compared to the first station of the central dumpsite, results showed that the second station of the central dumpsite (CDS 2), similarly had NOAEL and LOAEL at concentrations of 25 and 50ppm respectively (Table 25). However, a dissimilar mortality rate of the LOAEL was induced at 23.33%. Notwithstanding, the minimal lethal concentration (LC_{100}) value of CDS 2 was demonstrated a concentration of 175ppm within similar exposure of 3 hours compared to CDS 1. Based on the

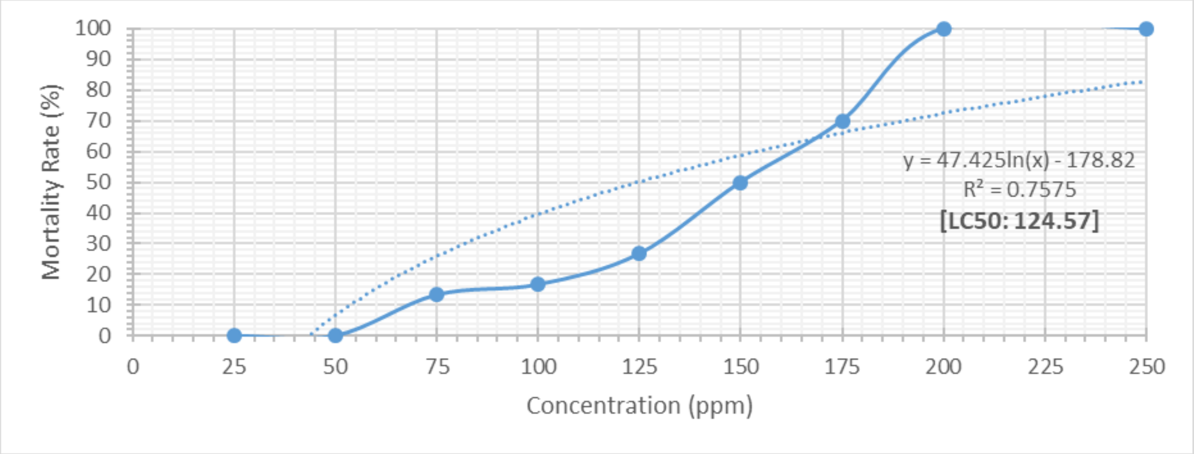

Figure 1. Dose-Response of Leachate from Akenpai Station

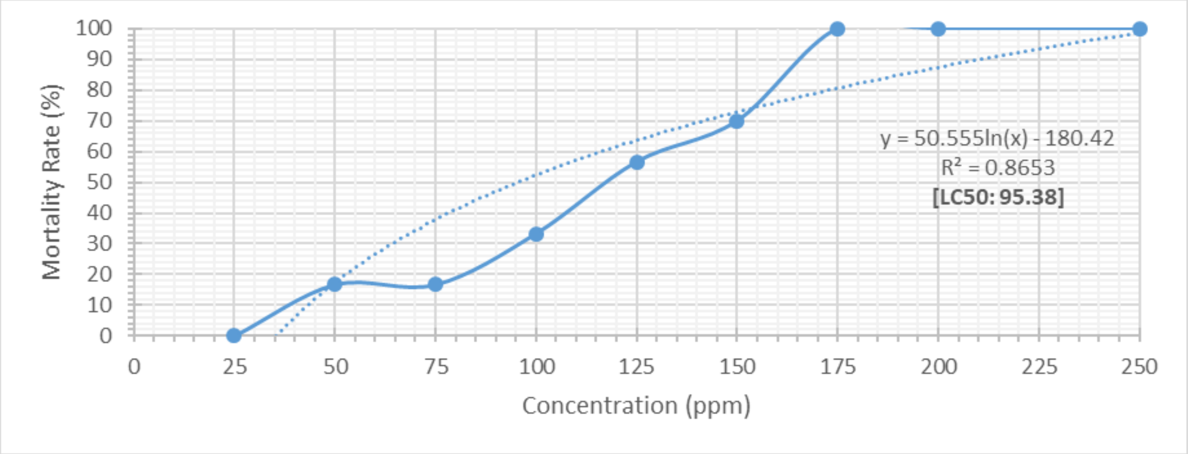

Figure 2. Dose-Response of Leachate from Etegwe Station

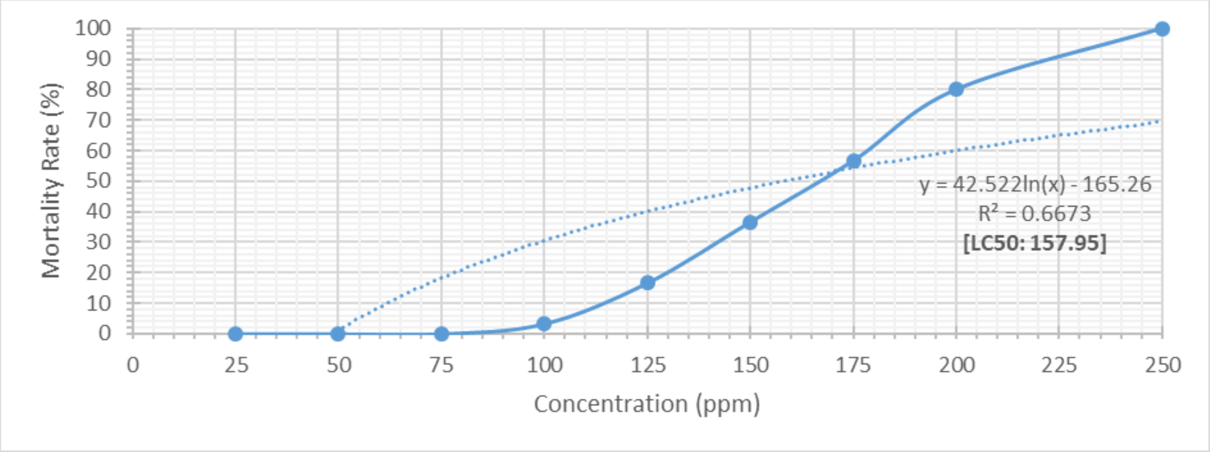

Figure 3. Dose-Response of Leachate from Opolo Market Station

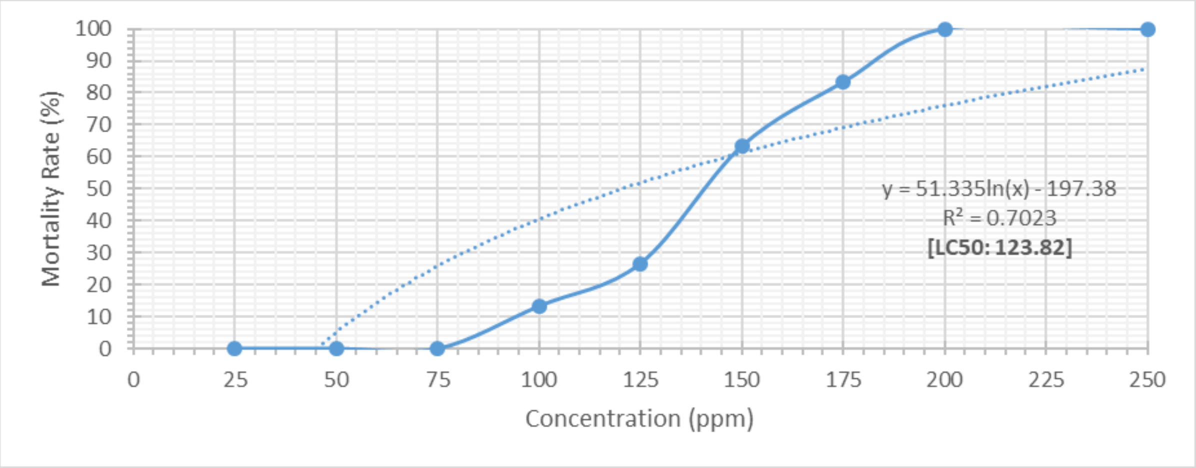

Figure 4. Dose-Response of Leachate from Kpansia Market Station

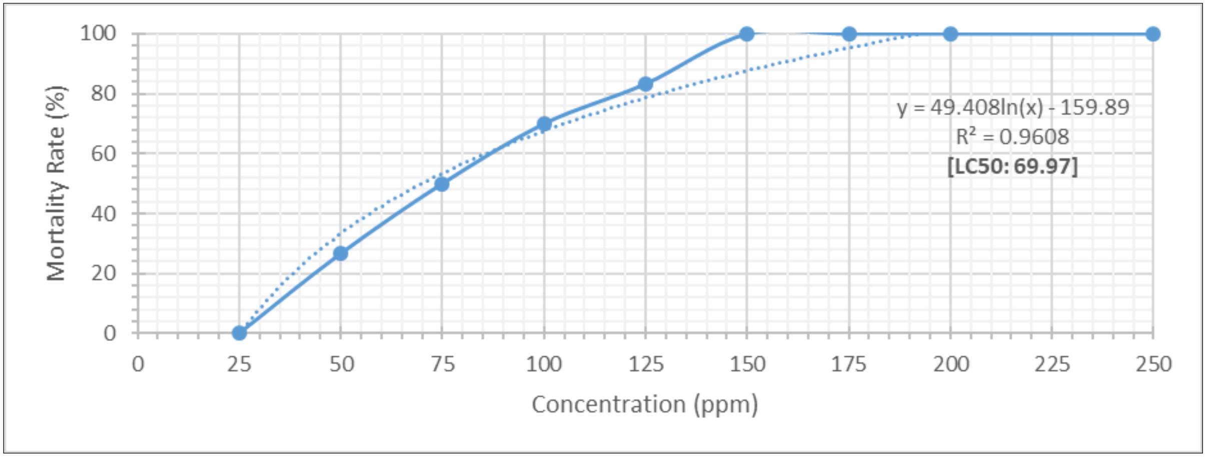

Figure 5. Dose-Response of Leachate from First Station of the Central Dumpsite

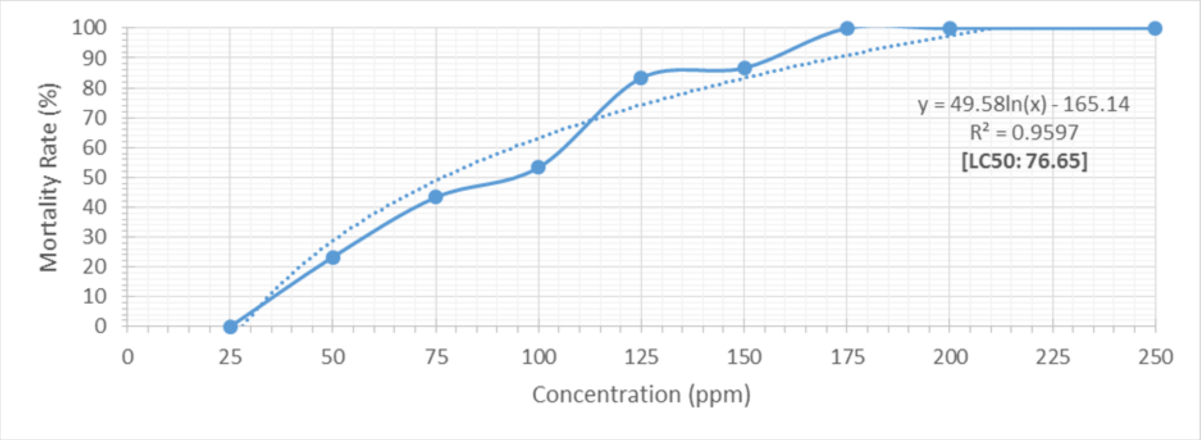

Figure 6. Dose-Response of Leachate from Second Station of the Central Dumpsite

statistical dose-response analysis the CDS 2 demonstrated toxicity with LC_{50} value of 76.65ppm (Figure 6).

On a general basis the order of toxicological activities of the leachates are reported as; CDS 1<CDS2<Etegwe< Akenpai<Kpansia market<Opolo Market. An earlier study of the characterization of leachates from the Niger Delta reported the levels of heavy metals in leachate as; Cadmium (0.00 – 0.17 mg/l), Chromium (0.00 – 0.46mg/l), Copper (0.00 – 0.70mg/l), Manganese (0.20 – 0.60mg/l), mercury (0.00 – 0.27 mg/l), Fe (0.20 – 8.41mg/l), lead (0.27 – 2.77 mg/l) and Zinc which ranged from 0.00 – 4.10 mg/l [12]. In their study, the order of toxicological activities of the heavy metals were; Iron>Lead>Zinc>Manganese>Copper>Chromium>Mercury>Cadmium [12]. The toxicity of the leachates from MSW dumpsite is largely attributed to the presence of heavy metal. Notwithstanding, high level of iron is not farfetched as it is a typical characteristic of the Niger Delta region [8, 13 - 14]. Another study by Ohimain et al., [8], reported high mortality of in a bioassay of ground water containing high level of iron (5.119 - 11.131mg/l), with acidic pH (3.97 - 6.40) against fingerlings of *Clarias gariepinus*.

The result on pH of leachate from Jeram Sanitary Landfill in Malaysia was less acidic (7.35), the BOD and COD levels were 27,000 and 51,200 mg/l respectively, with acute toxicity test against *Orechromis mossambicus* indicating LC_{50} value of 3.2% v/v [15]. Comparatively, leachate of our study was more acidic. However, the acidity of leachate from dumpsite may vary depending on its characteristics in terms of maturity and stability [15, 16], type of waste stream and even climatic condition of the location. Other factors may include waste composition, technology adopted, and the dumpsite mode operation, physicochemical properties, meteorological and hydrogeological [17, 18].

Another author reported mortality of dumpsite leachate against tilapia specie (*Sarotherodon mossambicus*) with LC_{50} values of 1.4 and 12% v/v in two respective sampling months [19]. Toxicity test of leachate using fish Tawes was carried out and result demonstrated toxicity with LC50 value of 0.358%, with clinical signs of protruded eyes and brown skinned stomach [20]. Carp (*Cyprinus carpio*) from Malasia were tested against dumpsite leachates from three different locations, results had COD and ammonia levels of 1640 - 7600 mg/l and 321.22 - 956.86 mg/l respectively, and also toxicities were demonstrated with LC_{50} values of 1.132, 2.0 and 3.822% respectively [21].

As reported by Sisinno *et al.* [22] the 48hours acute toxicity of pure and treated dumpsite leachate were investigated against zebrafish (*Brachydanio rerio*) with LC_{50} values of pure leachate samples inclusive in the range of 2.2 - 5.7% (v/v). Another author reported LC50 values as 19.2% and 53.0% after 48 hours for adults and fingerlings of Japanese killifish medaka (*Oryzias latipes*), respectively [23].

Conclusion

The research investigated the toxicological activities of leachate from Municipal Solid Waste dumpsite. The results obtained revealed varying degree of toxicity from the leachates. The highest degree of toxicity was demonstrated from the most acidic leachate, with more adverse effect on the fingerlings. This study confirmed that leachates from dumpsite are toxic to biodiversity. Hence policies to characterize, treat, reduce, reuse and recycle waste stream should be encouraged. In addition regulators and all stakeholders should enact laws to check anthropogenic activities.

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