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Impact of Olusosun Landfill Leachate on the Growth and Germination of *Celosia Argentea*

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Abstract

Landfilling is the major solid waste disposal method used in highly populated cities such as Lagos state, Nigeria and it remains the most important technology for municipal solid waste management. Despite its wide use and advantages, the challenges engendered by the production of leachates have generated grave concerns because of its impacts on nearby agricultural lands and/or underground water. This necessitated this research which seeks to assess the impact of leachate contaminated soil on the growth of a common vegetable; *Celosia argentea*. Leachates from Olusosun landfill site was sourced and used in treating uncontaminated fertile soil. Seeds of *C. argentea* were then planted in two replicates each on soil treated with leachate at the following concentrations; 20, 40, 60, 80, 100 and 200ml/kg of soil. The day of seed germination, number of leaves, leaf area and stem height were determined. The result showed that seeds planted in the control and leachate-treated soil at 20ml/kg, 40ml/kg, 60ml/kg and 80ml/kg of soil germinated on the 4th day while seeds planted in soil treated at 100ml/kg and 200ml/kg germinated on the 18th and 21st day after planting respectively. Number of leaves, leaf area and stem height in leachate-treated soil at 20ml/kg, 40ml/kg, 60ml/kg and 80ml/kg of soil were significantly higher ($P<0.05$) than the control but lower in soil treated at 100ml/kg and 200ml/kg. Generally, *C. argentea* witnessed growth enhancement in soil treated with leachate at concentration lower than 80ml/kg and witness growth inhibition in soil treated with leachate above 80ml/kg of soil.

Keywords: Olusosun, Landfill; Leachate; *Celosia Argentea*; Growth Inhibition

Introduction

Landfill is an area of land upon or into which waste is deposited. The aim of the technology is to avoid any contact between the waste and the surrounding environment, particularly the groundwater [1]. Landfilling is the major solid waste disposal method used in modern cities and it remains the most important technology for municipal solid waste management [2,3]. It was estimated that 0.5kg to 4.5 kg per person per day of solid waste is produced in different regions of the world and about 95% of total municipal solid waste (MSW) collected worldwide is disposed of in landfills [4]. The fact that it is the cheapest way of disposing municipal solid wastes makes it readily available in many communities; however, all efforts to get rid of wastes also pollute the environment to some extent [5].

The hosting of landfills in communities has also lead to another pollution challenge, especially when disposing municipal solid waste with high moisture and organic content [6]. This calls for serious concern, as pollution of new environment with activities from landfill is enormous. One prominent discussion on the pollution challenges of landfill has been centered on the pollution potential of landfill leachate [7,8]. Landfill leachate is the wastewater that originating from a landfill. Leachate forms when the soluble components present in the solid wastes, dissolves and leach out as water moves through the landfill [9]. A combination of physical, chemical, and microbial processes in the waste transfer pollutants from the waste material to the percolating water [10]. Groundwater and soil contamination by leachate remains a major concern in the operation of landfills due to its potential health risks [11].

Many landfills in Nigeria have not been designed to protect the environment from pollution and there are only two sanitary landfills in the whole country. Sometimes the sanitary landfill equipment breaks down. The landfill then in effect becomes an open dump, as waste is no longer compacted and covered properly. Burning becomes frequent and scavengers and workers run the risk of contracting respiratory diseases as they inhale smoke [12]. One of the prominent landfill sites in Nigeria is the Olusosun landfill in Lagos. The designed area of waste placement for Olusosun is 42 Ha [13]. The site had been used in the past as a burrow pit where sand was mined for road construction. Initial excavation depth of 7 to 12 m existed before tipping of waste commenced. The landfill accepts, officially, non-hazardous solid wastes of domestic, market, commercial, industrial and institutional origins but in practice all types of wastes are co-disposed. Its operation and maintenance were to be governed by stringent regulatory standards, but this has not been the case in practice [14]. As in most landfill, rain water moving through heap of waste mix up with liquid or decomposed waste and in some cases also dissolve solid soluble waste to produce leachates which either seep into groundwater or move along with flood. This makes it the greatest contamination threat to groundwater and most often it contains toxic substances especially when wastes of industrial origin are landfilled [15].

The environmental impacts of leachates emanating from dumpsites are greatly influenced by their heavy metal contents. These heavy metals are most times taken up by plants grown in contaminated soils as several studies have indicated that vegetables grown in heavy metals contaminated soils have higher concentrations of heavy metals than those grown in uncontaminated soils [16]. The effects of these metallic contaminations are of great concern, particularly in agricultural production systems due to their increasing trends in human foods and environment. Metals most often found as contaminants in vegetables include As, Cd and Pb [17,18]. These metals pose significant health risk to humans, particularly in elevated concentrations above the very low body requirements. So, the metals must be controlled in food sources in order to assure public health safety [19]. Absorption and accumulation of heavy metals in plants are influenced by many factors, including: concentration of heavy metals in soil, composition and intensity of atmospheric deposition, as well as irrigation with wastewater or waste leachate, the administration of organic and mineral fertilizers with the load of heavy metals, or application of pesticides, which contain in their structure such chemical elements [20]. Also, industrial and domestic wastes have been identified as some of the anthropogenic channels through which heavy metals are introduced into the soil [21]. Heavy metals are not biodegradable and are largely immobile in the soil system which promotes their accumulation in plants [22]. Accumulation of heavy metal in soil has the potential to alter the physicochemical properties of the soil, cause toxicity to plant and contaminate the food chain through it accumulation in edible plants such as *Celosia argentea* [23].

Celosia argentea is a vigorous, broadleaf vegetable belonging to the Amaranth family (*Amaranthaceae*). Its common names include Lagos spinach, quail grass, soko, celosia, feather cockscomb. *C. argentea* is grown successfully in temperate as well as tropical regions and is cultivated as a nutritious leafy green vegetable. It is one of the leading leafy green vegetables in Nigeria. The nutrient content in *C. argentea* varies between cultivated varieties; it has been noted that green-leaved varieties generally are more palatable and have higher protein and ascorbic acid (vitamin C) content than red varieties [24]. Medicinal uses of *C. argentea* have been reported where its use as a leafy vegetable has been adapted into the culture [25]. Considering the environmental impacts of landfill leachates and the location of Olusosun landfill, this research seeks to study the impacts of leachate from Olusosun landfill on the growth and germination of *C. argentea*.

Materials and Methods

Study site

Olusosun landfill is located at the North of Lagos State in Ojota community along the Lagos-Ibadan expressway, South-West Nigeria. It is situated between 6°23'N; 2°42'E and 6°41'N; 3°42'E [26]. The Landfill site began operations in 1992 and has a capacity of about 22,000,000 metric tons (about 49 billion m3). The facility receives approximately 40% of the total waste deposits in Lagos State [27]. It is expected to close in 2025 with an estimated 95% of municipal wastes in place [13]. The study was carried out ex-situ in the Research Unit of Botanical Garden, University of Lagos, Lagos, Nigeria.

Experimental materials

Fresh and old untreated leachates were collected from different sections of the landfill and mixed then transported to the Research Unit of Botanical Garden, University of Lagos, Lagos, Nigeria. Also, two samples (0.5L sample) of landfill leachate were collected in pre-sterile bottles and brought to the laboratory immediately after sampling and stored at a temperature of 4°C ± 1 for 24 hrs. The samples collected in the pre-sterile bottles were analyzed for heavy metal (Cd, Cr, Ni, Pb and Zn) contents of the leachate in the Analytical laboratory at the Department of Chemistry, Faculty of Sciences, University of Lagos. The seed of *Celosia argentea* and composite soil used was obtained from the Research Unit of Botanical Garden, University of Lagos, Nigeria. Healthy looking seeds were selected for the experiment and were washed in deionized sterile water before planting.

Experimental design

The experimental setup contains six pots of soil sample labelled (A-F) in two replicates. The soils in the pots were pre-treated with leachate at different concentrations of (20, 40, 60, 80, 100, and 200) ml/kg of soil and an untreated sample was set aside to serve as control. The treated soils were left for three days before planting seeds of *Celosia argentea*. The setup was watered daily with ordinary water.

Determination of plant growth parameters

The parameters employed to determine plant growth are; number of leaves, leaf area and stem height. The parameters were observed and recorded weekly for six weeks after planting. The plant height was measured with a meter rule. The leaf area of the plant is the product of the length and breadth of the leaf measured with the meter rule according to [28]. Also, the germination rates for the seeds were recorded.

Statistical analysis

Results at the end of 6th weeks were presented as mean of the 2 setups while growth inhibition are expressed as Mean value + Standard Error of Mean (SEM). Percentage growth inhibitions (GI) were calculated with the formula:

$GI = A - B/A \times 100$

Where A= Growth in control; B= Growth in treated group. Analysis of variance (ANOVA) was determined using SPSS 21.0 version software. Significant relationship was placed at ($P<0.05$).

Results

Heavy metal component of landfill leachate

Table 1 shows the heavy metal concentrations in Olusosun landfill leachate with Zn (1.67mg/L) having the highest presence followed by Pb (0.13mg/L).

Heavy metals	Concentration (mg/L)
Zinc (Zn)	1.67
Nickel (Ni)	0.04
Lead (Pb)	0.13
Cadmium (Cd)	0.04
Chromium (Cr)	0.04

Table 1: Olusosun landfill leachate heavy metal content

Germination study

Results revealed that seeds planted in soil with leachate concentrations lower than 100ml/kg (20ml/kg, 40ml/kg, 60ml/kg, 80ml/kg) as well as the control setup germinated on the 4th day after planting while the seeds planted in soil treated at 100ml/kg and 200ml/kg germinated on the 21st and 18th day after planting respectively.

Growth assessment

Table 2 shows that the mean number of leaves in the control was lower than in the soil with the least leachate concentration (20ml/kg). The mean number of leaves further increased in the 40ml/kg treated soil and remained constant in the 60ml/kg. The number of leaves peaked at the 80ml/kg of soil with a drastic drop in number of leaves in the 100ml/kg and 200ml/kg leachate-treated soil. The relationship ($P = 0.000$) between concentration and number of leaves was highly significant ($P < 0.05$). Growth inhibition in number of leaves was negative in all concentrations uptil the 80ml/kg and was positive at 100ml/kg (51.925%) and 200ml/kg (83.975) (Figure 1).

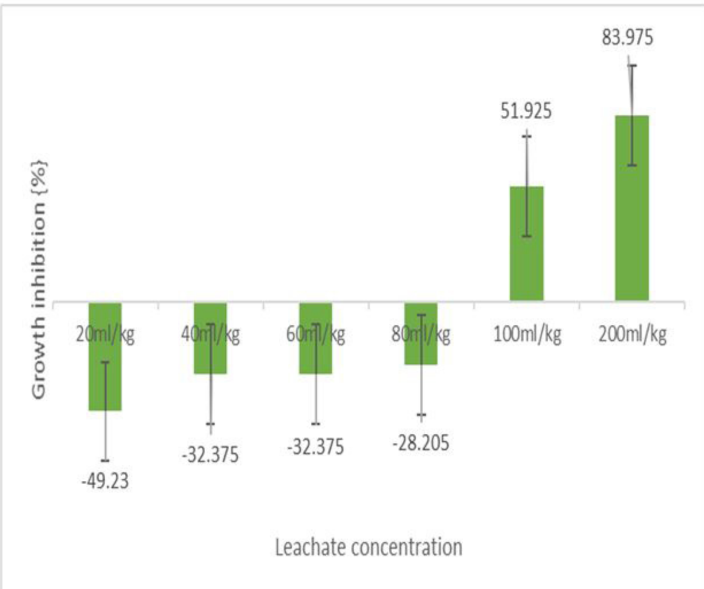

Figure 1: Growth inhibition in number of leaves of Celosia argentea planted in leachate treated soil

Concentration	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Growth inhibition
Control	4	7	8	10	11	13	
20ml/kg	6	7	9	12	13.5	17.5	-39.74 + 6.41[a]
40ml/kg	5.5	7.5	11	12.5	14.5	16.5	-32.38 + 9.30[a]
60ml/kg	6.5	7.5	10.5	10.5	14.5	16.5	-32.38 + 9.30[a]
80ml/kg	5.5	6.5	10	11.5	15	16	-28.21 + 5.13[a]
100ml/kg	-	-	2	4	5	6	51.93 + 1.93[b]
200ml/kg	-	-	1	2.5	3.5	4	83.98 + 0.65[b]

* Different letters (superscript) indicate statistical significance at $p < 0.05$

Table 2: Weekly number of leaves in Celosia argentae planted in untreated and leachate treated soil

The mean leaf area of *Celosia argentea* in the control soil was lower than those in 20ml/kg, 40ml/kg, 60ml/kg and 80ml/kg leachate-treated soils; all values of which were averagely the same. However, there was a decrease in the mean leaf areas of plants in 100 and 200ml/kg leachate-treated soil. The relationship (P= 0.003) between concentration of leachate in soil and leaf area was highly significant (P< 0.05). Figure 2 shows inhibition of growth concerning leaf area only at 100ml/kg (77.19%) and 200ml/kg (96.46%) (Table 3).

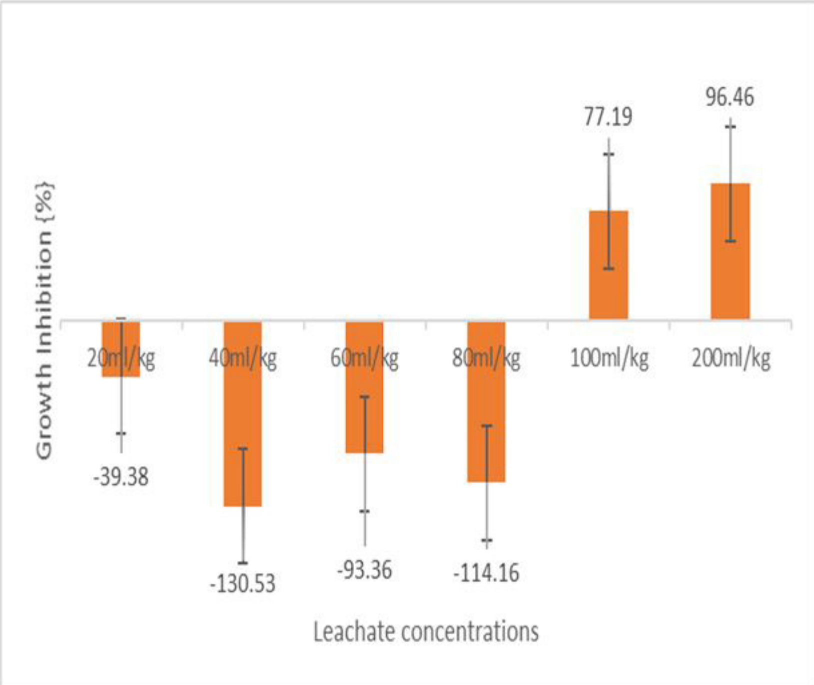

Figure 2: Growth inhibition in leaf area of Celosia argentea planted in leachate treated soil

Concentration	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Growth inhibition
Control	4.25	7.20	10.50	13.02	18.70	22.60	
20ml/kg	8.00	9.45	17.18	24.75	33.50	39.68	-82.01 + 42.63[a]
40ml/kg	9.87	14.26	28.75	31.65	47.30	55.55	-153.77 + 23.24[a]
60ml/kg	10.55	13.50	25.40	30.66	40.95	47.50	-117.11 + 23.75[a]
80ml/kg	6.20	13.30	32.41	29.10	43.85	48.85	-122.81 + 8.65[a]
100ml/kg	-	-	0.18	0.57	1.90	3.90	77.19 + 8.16[a]
200ml/kg	-	-	0.10	0.16	0.65	0.80	96.46 + 0.00[a]

* Different letters (superscript) indicate statistical significance at $p < 0.05$

Table 3: Weekly value for leaf area of Celosia argentae planted in untreated and leachate treated soil

The mean stem height of *Celosia argentea* in leachate-treated soils were fairly constant but higher than that of the control except the 100ml/kg and 200ml/kg concentrations, which witnessed stunted growth (Table 4). The relationship (P = 0.002) between leachate concentration and stem height was highly significant (P<0.05). Figure 3 shows that growth inhibition was negative in lower concentrations (20ml/kg to 80ml/kg) but positively high in 100ml/kg (70.54%) and 200ml/kg (85.14%).

Concentration	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Growth inhibition
Control	4.00	4.30	6.00	11.30	12.5	14.00	
20ml/kg	4.35	4.75	9.75	14.00	18.55	21.55	-49.23 + 3.96[a]
40ml/kg	4.15	5.55	11.25	14.75	18.65	21.65	-49.86 + 1.21[ab]
60ml/kg	4.15	5.15	10.50	15.00	18.75	21.75	-50.73 + 8.84[ab]
80ml/kg	3.75	4.90	8.85	14.50	17.00	20.00	-38.58 + 6.82[ab]
100ml/kg	-	-	1.35	2.00	2.85	3.40	70.54 + 2.45[ab]
200ml/kg	-	-	0.50	1.00	1.85	2.15	85.14 + 0.68[b]

* Different letters (superscript) indicate statistical significance at $p < 0.05$

Table 4: Weekly value for stem height of Celosia argentae planted in untreated and leachate treated soil

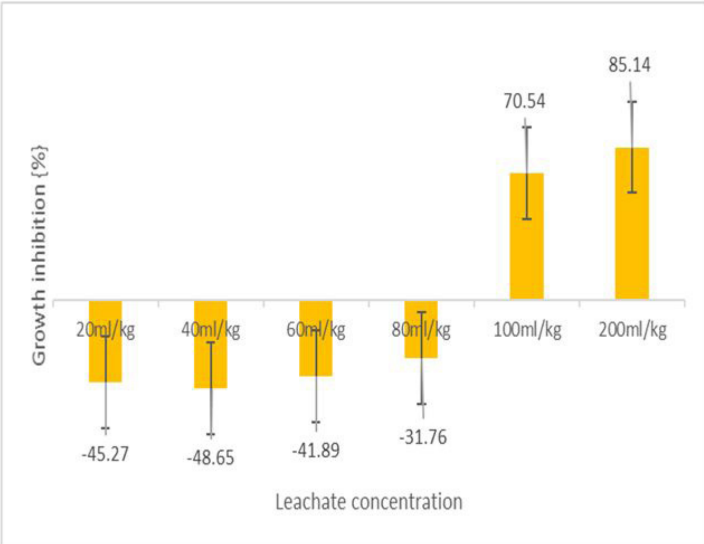

Figure 3: Growth inhibition in stem height of Celosia argentea planted in leachate treated soil

Discussion

The establishment of a new landfill site in Lagos state, Nigeria is imminent due to the geometric increase in population subsequently resulting in a geometric increase in the amount of municipal solid waste generated in the state. Generally, the presence of landfill leads to the production of leachates containing spectrum of compounds especially heavy metals that affect the germination and growth of plants [29]. Hence, United State Environmental Protection Agency proposed toxicity tests based on seed germination and root growth for the evaluation of the impact of toxic discharge into the environment [30]. Therefore, in anticipation of the establishment of new landfill sites in Lagos state, Nigeria and its impacts on surrounding soil, this study assesses the impact of leachate from the foremost landfill site in Lagos State on growth potential of a common vegetable plant; *Celosia argentea.*

An assessment of the heavy metal content of the leachate revealed that Zn and Pb are the two prominent heavy metals in Olusosun landfill leachates. Ni, Cd and Cr were also present but in a lower concentration. The high presence of Zn in Olusosun landfill leachate has earlier been reported and can been attributed to the disposal of batteries and fluorescent lamps in landfills [31,32]. Also reported that the high presence of Pb in landfill can be attributed to the presence of paints materials, Pb batteries, photography processing materials and Pb based pipes present in the landfill waste materials present [33].

The plant growth parameters assessed are number of leaves, leaf area and stem height. The results of the study reveal that seeds planted in soil treated with leachate at lower concentrations (20, 40, 60 and 80ml/kg) grow better than the control soil while seeds planted in soil treated with leachates of higher concentration (100 and 200 ml/kg) had growth inhibition. This pattern of plant growth has also been reported in the work of Khoshgoftarmanesh and kalbasi where municipal waste leachate at 150t/ha and 300t/ha increased the straw and grain yield of rice compared to the control soil but decreased the yield at 600t/ha [34].

The mean number of leaves of *C. argentea* in 20ml/kg, 40ml/kg, 60ml/kg an 80ml/kg leachates treated soil were higher than that of the control and a great decrease was witnessed in the two highest concentration (100ml/kg and 20ml/kg) when compared with the control soil. The increase in the number of leaves in soils treated with lower concentrations of leachates may be attributed to the increase in concentration of some other constituents such as nitrates and phosphate present in the leachate. Nitrates and phosphates are good source of nutrient for plant and aid plant growth at lower concentrations [35,36]. The other two plant growth parameters (leaf area and stem height) followed the same pattern with that of number of leaves and that's because overall plant growth is positively affected with substances containing small amount of nutrients especially nitrates, phosphates, sulphates, calcium etc, although, these same element at very high concentrations are not favourable for plant growth [36].

The toxic impact of leachates on plant germination and growth is a function of the content and concentration of the different components making up the leachates. Evidently, contamination of soil by landfill leachates at lower concentrations can be said to be beneficial to plants, specifically *C. argentea*. However, at higher concentrations, landfill leachates tend to be more of detrimental, than beneficial, to plant's survival; resulting in underdevelopment, stunt growth, chlorosis or even death. This confirms the report from several previous studies that, leachates induce both positive and negative responses in plants [30,32,37].

Conclusion

Leachates from Olusosun landfill site, Lagos state, Nigeria contains heavy metals such as Pb, Zn, Ni, Cd and Cr at varying concentrations. The presence of these heavy metals in the leachates affects seed germination and plant growth. At concentrations below 80ml/kg of soil, seeds planted in soil contaminated with leachates germinate same day as uncontaminated soils but seed germination was delayed for several days in soil contaminated with leachates above 80ml/kg of soil. The growth pattern shows that Olusosun landfill leachates is beneficial to the growth of *C. argentea* at concentrations below 80ml/kg of soil but highly detrimental and led to stunted growth of *C. argentea* at concentrations above 80ml/kg of soil. Therefore, efforts must be geared towards preventing the contamination of soil with leachates above 80ml/kg of soil. Consequently, concerted effort should be made by stakeholders towards the establishment of controlled and properly regulated landfills in order to reduce the rate of contamination of surrounding soils by leachates, thereby ensuring sustainable agricultural yield.

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