

Nigerian Journal of Ecology (2016) 15(2):19-29.
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ISSN: 1116-753X

Assessment of heavy metals and Total Petroleum Hydrocarbons accumulation in Tomato (*Solanum lycopersicon* L.) grown on Spent Oil polluted soil

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(Accepted 30 October 2016)

ABSTRACT

Oil-polluted soils make agricultural lands less productive and unsuitable for food production particularly increasing toxic levels of certain crops. The environmental concern is exacerbated by indiscriminate discharge of Spent Lubricating Oil (SLO) on agricultural land in Nigeria. This study evaluated the accumulation of heavy metals (Copper (Cu), Nickel (Ni) and Lead (Pb)) and Total Petroleum Hydrocarbons (TPHs) in tomato plants grown on spent oil- polluted soil. The treatments were 0, 75, 150 and 300 mls levels of pollution, replicated five times and laid out in a completely randomized design. Data were collected on plant growth and yield parameters and analysed using ANOVA at $p \leq 0.05$. There were significant decrease in plant height, number of leaves and stem diameter with increase in levels of spent oil pollution. The control (0ml) recorded significant increase in plant height (40.10cm), number of leaves (15.00) and stem diameter (0.50cm). The average fruit weight in the control was 0.80g while there were no fruits in other treatments. The highest dry weight (0.87g) was from the control while the lowest (0.69 g) was recorded from 75 mls treated plot. There was a general reduction of heavy metal concentrations in the soil with Cu having (7.38mg/kg) and Pb (0.70mg/kg) at 300 mls treatment while Ni was not detected. The control recorded the lowest TPH of 200mg/kg while the 300mls treatment had the highest 2800 mg/kg. In the plant shoot and root; Cu was higher (16.30mg/kg) in the root than in shoot (6.84mg/kg) while Pb (0.41mg/kg) in the shoot was higher than the root (0.21mg/kg) at 300 mls. This study shows that tomato plants could not survive the lowest (75mls) level of pollution; which signifies that small amount of spent oil in soil is unsafe for food crop production and consumers due to high levels of heavy metals and Total Petroleum Hydrocarbons

Keywords: Tomato-plant, Heavy metals, Total Petroleum Hydrocarbons, Spent Oil,

INTRODUCTION

Soil quality is of fundamental importance in agricultural production with soil fertility management increasingly becoming a central issue in the decisions on food security, food quality and quantity, poverty reduction and environmental management (Agamuthu *et al.*, 2010; Nwoko, 2010).

Spent lubricant or waste engine oil, is usually obtained after servicing of vehicles and hydrocarbon powered engines. It is improperly disposed in gutters and on farmlands causing soil contamination; becoming an environmental pollutant in Nigeria (Anoliefo and Vwioko, 2001; Ayotamuno *et al.* 2006).

The adverse effects of pollution on soil environment as reported by Bong *et al.* (1996) and Wyszokowski *et al.* (2004) limit the soil protective functions, upset metabolic activities and chemical characteristics thereby affecting plant production. It also affects microbes and aquatic lives (Nwoko *et al.*, 2007; Adenipekun *et al.*, 2008). It has been reported that spent oil contained large amounts of pollutants such as highly toxic poly aromatic hydrocarbons (Wang *et al.*, 2000) and heavy metals; iron, nickel, copper, aluminium, lead and vanadium (Helmenstine, 2013). The oxides, hydroxides, carbonates, exchangeable cations of these pollutants may also be retained in soils (Okonokhua *et al.*, 2007).

Heavy metal toxicities on plants have been studied at the level of biochemical-physiological process such as transpiration (Pandey and Sharma, 2002), photosynthesis (Kupperet *et al.*, 2002), enzyme activities (Astolfi *et al.*, 2005) or metal accumulation in tissue (Palmieri *et al.*, 2005). Oil-polluted soil has been shown to contribute to a reduced oxygen content of the soil due to the waxy nature of such soil. This may be due to the blockage of pore spaces in the soil, thus causing stress on plants. Baker (1970) reported that oil penetrated and accumulated in plants cause damage to cell membranes and leakage of cell contents.

Consumption of fishes, animals or plants that store heavy metals and hydrocarbons in the food chain had resulted in negative impacts on human health and the environment through bioaccumulation (Ritter *et al.*, 2007). Abnormal diseases in human beings indirectly exposed to these toxic pollutants had been well documented (Zakrzewski, 2002; Aigbedion, 2005). Several studies conducted on crops grown on spent oil-polluted soil; *Amaranthus hybridus* (Omosun *et al.*, 2008), *Solanum melongena*, *Ricinu scommunis* (Vwioko and Fashemi, 2005), *Arachis hypogea* (Ogbuchi

et al., 2011) and *Vigna unguiculata* (Lale *et al.*, 2014) revealed progressive depression in growth and yield parameters.

Tomato (*Solanum lycopersicon* L.) is one of the important fruit vegetable crops worldwide, belonging to the nightshade family Solanaceae (Hanson *et al.*, 2001; FAO, 2011). Globally, Nigeria is ranked 16th position for tomato production and this accounts for 10.8% of Africa and 1.2% of total world production. Cultivated area of 4.7million hectares had been recorded to produce 159 million tonnes globally and an average yield of 33.6 ton ha⁻¹ (FAO, United Nation, 2013). This vegetable is cultivated in commercial quantity in the northern parts of Nigeria, but along with other crops on farms all over the country (Anoliefo and Vwioko, 1995). The tomato fruit is an important source of ascorbic acid (Vitamin C), β -Carotene and mineral elements (Tindal, 1992; Hector *et al.*, 2002).

Several studies on the deleterious effects of heavy metal concentrations and spent lubricating oil on tomato were reported on the seedlings and growth of the plant (Anoliefo and Vwioko, 1994; Raskin and Ensley, 2000; Yaqvob *et al.*, 2011). However, studies on the accumulation of heavy metals and hydrocarbons in tomato plants and polluted soil are scanty. These pose high public health risk challenges as plant consumers are exposed to these toxic pollutants. This study therefore, was carried out to assess the heavy metals and Total Petroleum Hydrocarbons (TPHs) accumulation in tomato plants (*Solanum lycopersicum*) and spent oil- polluted soil.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the open roof top experimental site of the Department of Crop Protection and Environmental Biology (CPEB), University of Ibadan, Nigeria. The experimental site

(CPEB) falls within latitude 7.43°N and longitude 3.54°E at an altitude of 200m. It has an annual rainfall between 1250-1500mm spanning eight months (March – October) with dry spell in August; average temperature of 21.30°C and relative humidity of 70-80%.

Soil sampling

Top soil (0-15cm) samples were randomly collected from the open field between the Departments of Crop Protection and Environmental Biology and that of Forestry, both of the University of Ibadan, Nigeria. The composite soils were air – dried, thoroughly mixed and passed through a 2mm sieve to remove the non-soil materials. The heavy metal contents of the soil before and after contamination were determined.

Soil preparation and planting

A uniform quantity of top soil (5 kg) was placed in experimental plastic pot (20cm x 60cm). Four levels of pollution were induced by mixing the soil with 0, 75, 150 and 300 mls of spent oil with 0ml treatment serving as control and the pots were arranged in a completely randomized design and replicated five times. The polluted soil filled pots were thoroughly mixed and left for two weeks for full actualization of homogeneity. The tomato seeds (RIO GRANDE) were purchased from an agricultural seeds store at Bodija, Ibadan, Oyo state. They were raised in the nursery at the screen house of the Department of Crop Protection and Environmental Biology, for three weeks. Three seedlings were transplanted into each pot containing different levels of spent oil-polluted soil and thinning was done to two seedlings/pot at three weeks after sowing (WAS).

Data collection

Growth parameters such as plant height, number of leaves, stem diameter and number of flowers of tomato plants were measured and monitored using meter rule, visual count and Vernier caliper, respectively from two weeks after transplanting (2WAT) fortnightly for six weeks. The yield parameters: fruits, fresh and dry weights were determined at maturity and at harvesting.

Chemical analyses

Plant dry weight determination: Harvested plants were washed with deionized water and separated into shoots (leaf +stem) and roots after which they were oven- dried at 70°C till constant dry weight to determine biomass.

Heavy metal analysis: Heavy metal analyses were carried out at the Soil Analytical Laboratory of the Department of Agronomy and Multidisciplinary Central Laboratory (MCL), University of Ibadan, using the method of AOAC (2005). Five (5) grams of soil and the dried plant parts; shoots (leaf + stem) and roots were ground in a stainless steel mill, respectively. The soil and ground plant samples were digested in a fume chamber with nitric acid (HNO_3) and perchloric acid (Chloric (VII) acid) (HClO_4) in the ratio 3: 1. Copper, Lead and Nickel concentrations were then measured using an Atomic Absorption Spectrophotometer (Bulk Scientific, Model 210 VGP)

The Total Petroleum Hydrocarbons Analysis: This was determined by the method of Adesodun and Mbagwu (2008). Ten grammes (10g) of soil were weighed into 50ml flask and 20ml Toluene (Analar Grade) was added. After shaking for 30minutes on an orbital shaker, the liquid phase of the extract was measured at 420

nanometer (nm) using DR/4000 spectrophotometer. The Total Petroleum Hydrocarbon in the soil was estimated with reference to a standard curve derived from fresh used engine oil diluted with toluene.

Data analysis

All the data collected on the growth and yield parameters, heavy metals and total petroleum hydrocarbons on tomato and soil from this study were analysed using Analysis of Variance (ANOVA) at 5% level of significance ($p < 0.05$). Means were separated using Least Significant Difference (LSD).

RESULTS

Soil contamination with spent oil produced adverse effect on the growth performance of tomato plants, thereby

reducing crop growth compared to the control and the effect was concentration dependent as shown in Table 1. Results at 6 weeks after transplanting (WAT) showed that the plants grown on the soil treated with 300mls of spent oil withered. Control plants had the highest value of plant height (40.10cm), while addition of 75mls of spent oil to soil gave 11.80cm plant height. The number of leaves produced from the control also revealed progressive increase across the weeks with significant higher ($p < 0.05$) values (11.00-15.00) when compared with polluted treatments which decreased progressively from 10.60-1.40 and nothing in the treatment that received 300mls of spent oil at 6WAT. However, stem diameter followed the same trend as number of leaves (Table 1).

Table 1: Effects of spent oil pollution levels on the mean of plant height, number of leaves and stem diameter of tomato plants

Concentration	Plant Height (cm)			Number of leaves			Stem Diameter (cm ²)		
	2WAT	4WAT	6WAT	2WAT	4WAT	6WAT	2WAT	4WAT	6WAT
75mls	11.40	13.06	11.80	10.60	5.80	3.40	0.08	0.12	0.08
150mls	11.16	13.94	3.40	8.60	5.20	1.40	0.14	0.08	0.02
300mls	9.98	4.52	0.00	9.40	2.20	0.00	0.07	0.03	0.00
0ml (control)	16.24	30.60	40.10	11.00	14.00	15.00	0.26	0.31	0.50
LSD (0.05)	6.47	9.45	8.00	4.98	2.83	2.38	0.19	0.10	0.13

The number of flowers in the control treatment (11.00) significantly increased ($p < 0.05$), while the other treatments did not produce flowers and fruits. Only the control treatment yielded 0.80 g of fruit (Table 2).

The effect of pollution levels on dry weight of tomato plants is presented in Table 3. Significantly higher ($p < 0.05$) biomass 8.07g was obtained from the control treatment plants, while the polluted treatments; 75,150 and 300mls had similar values of 0.69, 0.81 and 0.76g, respectively.

Heavy metal concentrations (Cu, Pb and Ni) of polluted soil before transplanting of

tomato seedlings revealed significant differences ($p < 0.05$) which increased with the pollution levels as shown in Fig. 1. The minimum value of Cu, 19.90 mg/kg was recorded in the control soil, while the 300mls treatment had the highest value of 198.09mg/kg. Also, the lowest value of Pb 40.67 mg/kg was from the control; however, plots treated with 300mls had 1168.87mg/kg, while the highest value 1891.40mg/kg was from the 75mls treatment. Nickel on the other hand was not detected.

Table 2: Effects of spent oil pollution levels on mean number of flowers, number of fruits and fruit weight (g) of tomato plants

Treatment	Number of flowers	Number of fruits	Fruit weight (g)
75mls	0.00	0.00	0.00
150mls	0.00	0.00	0.00
300mls	0.00	0.00	0.00
Control (0)ml	11.00	3.00	0.80
LSD(0.05)	1.54	0.62	0.58

WAT- Weeks after transplanting

Results obtained for heavy metals after the termination of the experiment showed Cu concentrations in the soil not significantly different ($p > 0.05$) among the treatments as represented in Fig.2. The Pb concentration however, was significantly different ($p < 0.05$) among the treatments. The highest value of 0.70mg/kg was obtained from the 300mls treatment, while the lowest value of 0.05mg/kg was from the control. Nickel was not detected in the soil (Fig. 2).

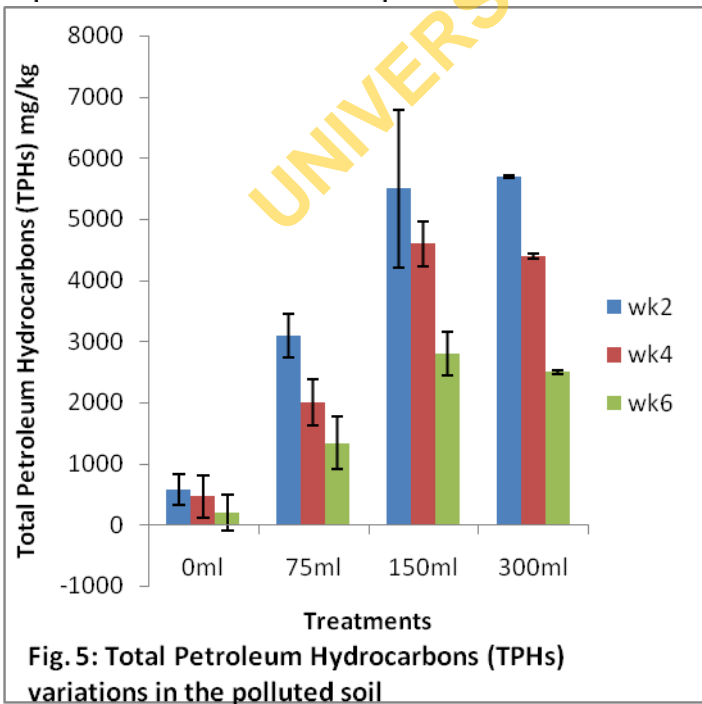
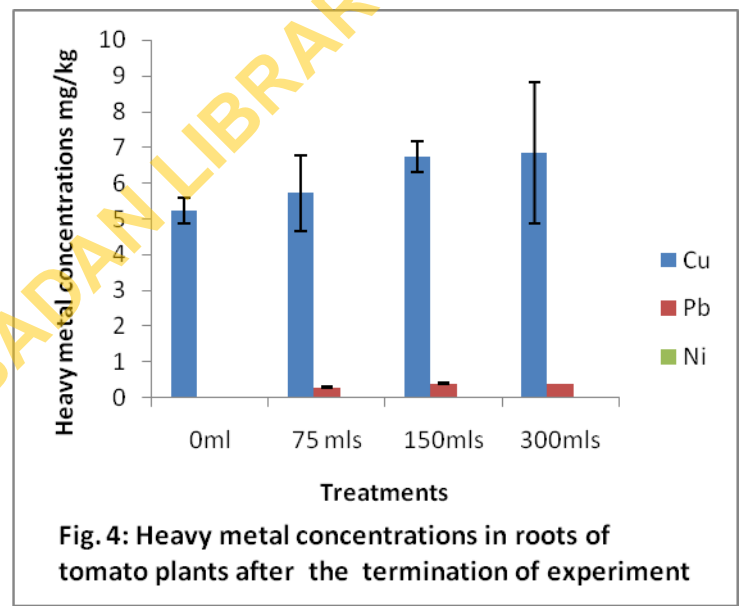
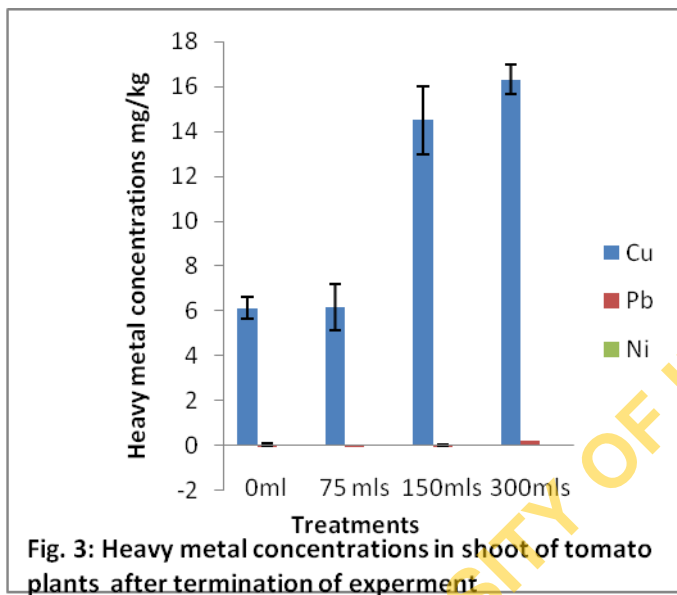
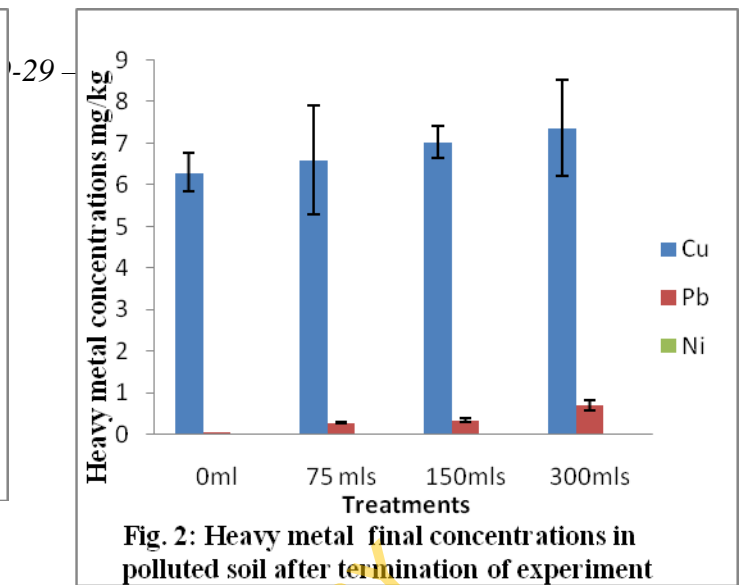
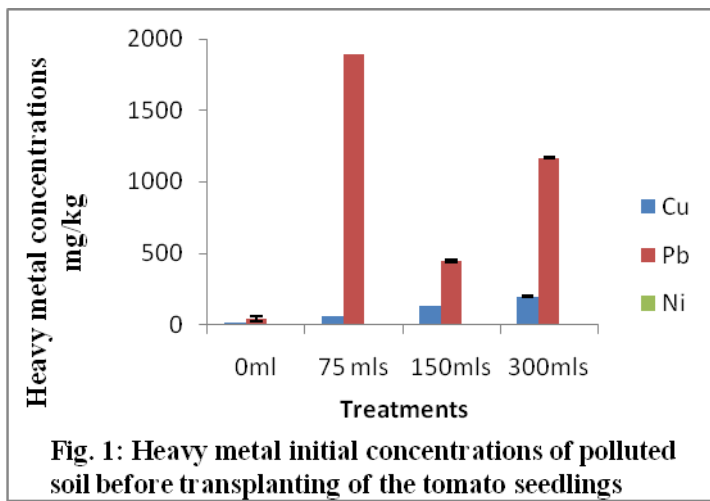
The heavy metal analysis results of tomato plant roots revealed significant increase ($p < 0.05$) in Cu 16.30mg/kg from the 300mls treatment, while the lowest value 6.14mg/kg was obtained from the control. However, on the other hand Pb revealed no significant difference ($p > 0.05$) among all the treatments (Fig. 3). Both Cu and Pb in

tomato plant shoots showed no significant difference ($p > 0.05$) among all the treatments. Although, the highest value of Cu; 6.84mg/kg was from the 300mls treated soil, while the lowest value; 5.23mg/kg was from the control. Also, the Pb in 300mls treatment had the maximum value of 0.41mg/kg and was followed closely by that of 150mls treatment which gave 0.39mg/kg, while the control had the lowest value of 0.05mg/kg (Fig. 4).

The Total Petroleum Hydrocarbons (TPHs) variations in the polluted soil of tomato plants are as shown in Fig.5. The control had the lowest value (200mg/kg) of TPHs compared to other treatments. Soil treated with 75mls gave the value of 1333.33mg/kg which was significantly different ($p < 0.05$) from that of 300 mls which had the highest value of 2800mg/kg.

Table 3: Effects of spent oil pollution levels on fresh and dry weights (g) of tomato plants

Treatment	Fresh weight (g)	Dry weight (g)
75mls	2.88	0.69
150mls	1.84	0.81
300mls	0.87	0.76
Control (0)ml	19.97	8.07
LSD(0.05)	4.87	2.35



DISCUSSION

The toxicity of the spent oil like any other petroleum products produced adverse effects on the growth and yield of tomato. The reduction in plant height noticed in oil-polluted soil could be due to decrease in uptake of nutrients of the tomato plants most especially the nitrogen, which is obtained from the decomposed soil micro-organisms (bacteria, fungi etc.). Since the petroleum products would have made them unavailable in soil (Agbogidi *et al.*, 2007). The toxic effects of spent lubricating oil (SLO) in reducing the growth parameters (plant height, number of leaves and stem diameter) in this study also conformed with the report

of Anoliefo and Vwioko (1995) that soil contaminated with spent engine oil caused growth retardation with adverse effects on tomato (*Solanum lycopersicum*). The negative effects of the SLO with increasing concentrations (concentration/dose-dependent) on the growth performance of *Solanum lycopersicum* such as plant height, number of leaves and dry weight of plant, observed in this study were similar to those reported by Okonokhua *et al.*(2007), Njoku *et al.*(2009) and Ogbuehi *et al.*(2011).

The toxic effects of spent oil pollution on crop productivity which include growth and yield parameters were shown clearly in this study. Some of the tomato plants showed stunted growth, leaf decoloration and premature death. It was only the control that was able to get to the flowering and fruiting stages. All these may be due to the presence of large amounts of heavy metals and hydrocarbons in the polluted soil which conformed to the work of Atuanya (1987) and Wang *et al.* (1996). The effects of aliphatic, aromatic and phenolic compounds in the Total Petroleum Hydrocarbons (TPHs) might have resulted into reduced respiration, transpiration and photosynthesis thereby producing systemic toxic effects of translocation of long chain alkanes to the stems (Siciliano and Gemida, 1998).

It was observed during this study that water did not penetrate down the soil in all polluted treatments and the soil was water logged. The petroleum hydrocarbons might have caused the polluted soil treatments to be waxy, interfered with gaseous exchange and contributed to the reduction of oxygen content in the soil which might have led to soil pores blockage and increasing water stress on the tomato plants. This was in agreement with the studies of Adams and Ellis, (1960); Atuanya, (1987); Anoliefo and Vwioko, (1995); Lale *et al.*, (2014) that, soils contaminated with oil become waxy and usually does not allow water to

penetrate and when wet, they become water-logged, reduce oxygen content, block the pore spaces in the soil, thus causing stress on plants.

It was found from this present study that, the initial concentration of Pb in the soil was lower in the highest polluted treatment (300mls) when compared with 75mls. This could be due to the soil microorganisms' activities (Magnuson *et al.*, 2001; Friedlov', 2010) which might have happened at a faster rate in the highest polluted soil especially after pollution (Nannipieri *et al.*, 1997). The tomato plants revealed a decrease in heavy metal concentrations at the end of the experiment when compared with the initial concentrations. This might be due to the accumulation of the heavy metals in the tomato plant which was in agreement with the work of Frederick and Ching (2014). The amount of heavy metals extracted by tomato plants could be directly linked with observed reduction in growth and yield parameters (Ogbuehi *et al.*, 2011). The uptake reduction observed in the heavy metal concentrations of the soil, plant root and shoot followed this decreasing order Cu>Pb>Ni. This is probably showed that the tomato plants have the potential to store more Cu in the soil. It was also shown that, root and shoot of tomato plants are the organs that accumulated highest level of Cu metal contamination over other metals (Frederick and Ching, 2014).

There was a higher percentage reduction in the final Total Petroleum Hydrocarbons (TPHs) of soil compared to the initial values which showed the possibility of TPHs degradation in soil (Agamuthu *et al.*, 2010). This was shown that, the tomato plants grown on the polluted soil might have reduced the quantity of the petroleum by accumulating it in their tissues, thereby leading to the lesser amount of TPHs in the treated soil. The effect of tomato plants on the reduction of TPHs from the soil polluted

with 75, 150 and 300mls spent oil is also similar to the findings of Aprill and Sims (1990), Lee and Bank (1993), Schwab and Banks, (1994) and Merkl *et al.* (2005) who reported higher degradation of petroleum in planted soils.

This present study has shown that tomato plants could accumulate heavy metals and total petroleum hydrocarbons, therefore, the observed reduction in growth and yield parameters of tomatoes could be attributed to the heavy metal accumulation in tomato plant (Ogbuehi *et al.*, 2011). Hence, soil polluted with waste oil may remain unsuitable for crop growth.

CONCLUSION

This study has been able to show that the negative effects of spent oil on growth parameters are dose dependent. Level of spent oil pollution at 75mls and above would have deleterious effect on growth and yield parameters of tomato plants. Concentrations of the heavy metals in the tomato plants were higher especially in Cu and Pb as reported in the study. Reductions in the Total Petroleum Hydrocarbons (TPHs) showed that, there was higher degradation of petroleum hydrocarbons by tomato plants; hence high accumulation of TPHs was found in the plant.

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