Soil contamination through oil spillage accumulates in the soil and affect plant growth. The study was conducted to examine the effect of spilled engine oil on soil nutrients and germination of seed in the in the Central region of Ghana. Ten samples were collected randomly from selected mechanic and fitting sites in the Elmina municipality. A randomized complete block design using three test crops was used to evaluate soil quality indicators such as N, P, K and soil pH on the polluted soil using standard methods. Maize recorded 3.67, 18.5 and 3.7% germination in contaminated soils from Aponkyedasoro, Nippon and Afitafum, respectively. Cowpea and sorghum recorded no germination in these soils. The three crops showed higher germination rates in the control soils, with the highest being recorded in sorghum (72.2%), followed by cowpea (70.4%) with the least being recorded in maize (66.6%). The results showed that nitrogen (N) level in the experimental soil was very low (0.065-0.075%) as compared to the control (0.115%) in this study. However, polluted soil from Aponkyedasoro, Afitaful and Nippon recorded a higher level of phosphorus (60.84-31.58 µg/g) and potassium (0.52-0.58 µg/g) than control (P=20.97 µg/g; K=0.43 µg/g) despite having a low germination rate. Copper, zinc, sodium and iron concentration were higher in the engine oil polluted soil. The study revealed that the concentration of heavy metals and spilled engine oil in the soil has a higher effect on plant development; hence, public awareness should be created of its detrimental effect on the ecosystem.

**Key words:** Contamination, germination, heavy metals, soil fertility.

**INTRODUCTION**

Land and water are precious natural resources on which rely the sustainability of agriculture and civilization of mankind (Ghassemi et al., 1995; Asiamah et al., 2020a, b). Unfortunately, they have been subjected to maximum exploitation and severe degradation due to anthropogenic activities (Apori et al., 2018; Essien and John, 2010). The pollution includes point sources such as emission, effluents and solid discharge from industries, vehicles,
exhaustion and metals from smelting and mining, as well as nonpoint sources such as soluble salts (natural and artificial) (Kayode et al., 2009; Vwioko and Fashemi, 2005). Moreover, the use of insecticides/pesticides, disposal of industrial and municipal waste in agriculture, and excessive use of fertilizer stimulate loss of soil fertility (Rowell, 1994). Each source of contamination has its own damage to plants and animals and ultimately to human health, but those that add heavy metals and spilled engine oil to soil and water are of serious concern, due to their persistence in the environment and carcinogenicity to plants growth (Vwioko and Fashemi, 2005). Studies have revealed a lower rate of plant germination, lower absorption of water and lower temperature of the soil environment as a result of oil contamination (Milala et al., 2015). Research has further concluded that water deficiency as well as insufficient aeration of the soil because of the displacement of air and water from the space between soil particles by oil retarded early germination and seedling growth coupled with chlorosis of leaves and dehydration of plant (Cutforth et al., 1986).

In Ghana, there are a lot of mechanic, fitting and welding shops, which are haphazardly located all over the country. Their works deal with changing the oil in cars, leading to the spilling of used engine oil (dirty oil) and heavy metals (Michael, 2015). These engine oils are derived from petroleum-based and non-petroleum-synthesized chemicals which often contaminate the environment. These oils are dumped in open plots of lands, into sewage and drainage ditches which usually enter into the aquatic chain through surface runoff (Milala et al., 2015). Infiltration of this affected runoff by spilled engine oil into the soil affects soil microbial diversity thereby decreasing its function regarding organic matter decomposition and microbial remediation of toxic contaminants (Cunningham et al., 1996). Small scale farmers and garden owners most often find their lands affected by this discarded engine oil, making soil unsatisfactory for plant growth. This research focused on major mechanic sites in the municipality of Elmina, in the central region of Ghana, where lands have been seriously contaminated by heavy metals and spilled engine oil at Aponkyedasoro, Nippon and Afitaum (Benz fitting shops). This work aims at investigating the effect of spilled engine oil polluted soil on plant development.

MATERIALS AND METHODS

Study area and experiment

The experiment was carried out in the botanical gardens of the University of Cape Coast (UCC) between January and April 2015. The experimental (polluted) soil samples were taken from three (3) mechanic and fitting sites in the Elmina municipality in the Central region of Ghana, namely, Aponkyedasoro, Afitaum (Benz fitting shops) and Nippon. Experimental soil samples were randomly fetched from the sites of study Aponkyedasoro, Afitaum (Benz fitting shops) and Nippon at a depth of 20 to 40 cm. Fifty-four slope-sided plastic pots with a lower and upper diameter of 20.7 and 27 cm respectively, the height of 23.5 cm and a total volume of 14000 cm$^3$ were used for the pot experiment. The base of each pot was perforated to allow for water drainage. Each pot was filled with 14.4 kg of fine earth fraction (< 2 mm) polluted soil. Twenty-seven (27) plastic pots were filled with control soil and twenty-seven (27) plastic pots were each filled with the experimental soil from the different experimental sites (that is nine (9) plastic pots for soil from each contaminated site) at an average weight of 14.4 kg. Three (3) different plant seeds (sorghum, maize and cowpea) were planted in each of the polluted and control soil. Both the experimental and the control soil were replicated 3 times for each of the plants. They were arranged in an independently randomized complete design according to the experimental sites. The soil was irrigated a day before planting. Four seeds were sown per pot for both the polluted and the controlled soil. After sowing, all cultural practices were observed (that is watering, thinning out).

Soil evaluation

The pH and electrical conductivity of the soil were measured in deionized water with a soil-to-deionized water ratio of 1:2.5 (w:v) following the DINSO standard 10390 for soil pH and conductivity measurements (Maghanga et al., 2012). For the pH, 0.5 g of soil was put in a test tube. 25 mL of deionized water was added and shaken for 1.5 h using a mechanical shaker. After shaking, it was allowed to settle for 5 min in which the pH meter was used to measure the pH. The electronic conductivity determination was also conducted on the same sample as used for the determination of the pH. Available P was analyzed using the Bray No. 1 acid extracting method (Maghanga et al., 2012). Potassium analyses were done using the NH$_4$O extract (Rhoades, 1982).

Total nitrogen was determined by the Kjeldahl method (Bashour and Sayegh, 2007). Micro-Nutrients (Zn$^{2+}$, Fe$^{2+}$ and Cu$^{2+}$) were determined by Atomic Absorption Spectrophotometer (AAS) [8].

Fe ($\mu$g/g) = C x solution volume / Sample weight

Cu ($\mu$g/g) = C x solution volume / Sample weight

Zn ($\mu$g/g) = C x solution volume / Sample weight

where C = concentration obtained from AAS.

Plant evaluation parameters determination

The chlorophyll content was taken every 2 weeks using the chlorophyll meter (CCM-200, Apogee) for 6 weeks. Plant growth parameters e.g. plant height, the number of leaves, stem diameter and chlorophyll content were determined by a method proposed by Kayode et al. (2009).

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Table 1. Germination rate of cowpea, sorghum, and maize in soils from the experimental sites.

| Crop      | Control     | Aponkyedasoro | Nippon     | Afitafum    |
|-----------|-------------|---------------|------------|-------------|
| Cowpea    | 70.4 ± 17.01| 0.00 ± 0.00   | 0.00 ± 0.00| 0.00 ± 0.00 |
| Sorghum   | 72.2 ± 10.71| 0.00 ± 0.00   | 0.00 ± 0.00| 0.00 ± 0.00 |
| Maize     | 66.6 ± 20.03| 3.67 ± 3.18   | 18.5 ± 32.0| 3.7 ± 6.41  |

Values are means ± standard deviation of means of three (3) replicates. Means of polluted soil are significantly different from control (p < 0.05), two weeks after planting.

Table 2. Stem girth (cm) of cowpea, sorghum, and maize in soils from the experimental sites.

| Plant      | Control     | Aponkyedasoro | Nippon     | Afitafum    |
|------------|-------------|---------------|------------|-------------|
| Cowpea     | 1.34 ± 0.12 | 0.00 ± 0.00   | 0.00 ± 0.00| 0.00 ± 0.00 |
| Sorghum    | 2.99 ± 0.16 | 0.00 ± 0.00   | 0.00 ± 0.00| 0.00 ± 0.00 |
| Maize      | 2.96 ± 0.06 | 0.14 ± 0.30   | 0.00 ± 0.00| 0.093 ± 0.246|

Values are means ± standard deviation of means of three (3) replicates. Means of polluted soil are significantly different from control (p < 0.05), five weeks after planting.

Table 3. Number of leaves of cowpea, sorghum, and maize in soils from the experimental sites.

| Plant      | Control     | Aponkyedasoro | Nippon     | Afitafum    |
|------------|-------------|---------------|------------|-------------|
| Cowpea     | 23.8 ± 3.89 | 0.00 ± 0.00   | 0.00 ± 0.00| 0.00 ± 0.00 |
| Sorghum    | 10.7 ± 0.61 | 0.00 ± 0.00   | 0.00 ± 0.00| 0.00 ± 0.00 |
| Maize      | 10.2 ± 0.10 | 0.53 ± 0.99   | 0.07 ± 0.26| 0.4 ± 1.06  |

Values are means; ± is the standard deviation of means of three (3) replicates. Means of polluted soil are significantly different from control (p < 0.05), five weeks after planting.

Data analysis

Data presented are means ± standard deviation (SD) of three independent replicates. Data were analyzed using a one-tailed analysis of variance. Means of significant difference were separated by Tukey’s multiple range tests at p < 0.05.

RESULTS

Effects of oil spilled soil on plant physiological performance

Generally, the three crops showed least or no significant (p < 0.05) rate of germination when grown on spilled engine oil polluted soil. Only maize recorded 3.67, 18.5 and 3.7% germination in contaminated soils from Aponkyedasoro, Nippon and Afitafum, respectively (Table 1). The rate of germination of maize was higher in contaminated soil samples from Nippon than in all the soil samples. Cowpea and sorghum recorded no germination in these soils. The three crops, however, showed higher germination rates in the control soils, with the highest being recorded in sorghum (72.2%), followed by cowpea (70.4%) with the least being recorded in maize (66.6%) (Table 1).

No growth of cowpea and sorghum on the polluted soil, obviously had no stem (Table 2). Maize recorded stem girth of 0.14 and 0.09 cm on the polluted soils from Aponkyedasoro and Afitafum, respectively. Growing maize in soil from Nippon died three weeks after sowing. Stem girth of maize in Nippon was approximately zero. The three crops, however, showed higher stem girth in the control soils, with the highest being recorded in sorghum, followed by maize with the least being recorded in cowpea (Table 2).

Furthermore, maize recorded the mean number of leaves of 0.53, 0.07 and 0.04 in polluted soils from Aponkyedasoro, Nippon and Afitafum, respectively as shown in Table 3. The three crops, however, showed a higher record of the number of leaves in the control soils, with the highest being recorded in cowpea (23.8), followed by sorghum (10.7) with the least being recorded in maize (10.2) (Table 3).

The plant height for maize, sorghum and cowpea, when grown in the various experimental and control soils, was recorded two weeks after sowing (Table 4). Maize recorded mean heights of 0.06, 0.05 and 0.47 cm in polluted soils from Aponkyedasoro, Nippon and Afitafum,
Table 4. Plant height of cowpea, sorghum, and maize in soils from the experimental sites.

| Plant     | Control   | Aponkyedasoro | Nippon   | Afitatafum |
|-----------|-----------|---------------|----------|------------|
| Cowpea    | 13.6 ± 1.73 | 0.00 ± 0.00   | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Sorghum   | 46.2 ± 4.99 | 0.00 ± 0.00   | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Maize     | 41.67 ± 2.66 | 0.06 ± 0.16   | 0.05 ± 0.21 | 0.47 ± 1.23 |

Table 5. The chlorophyll content of cowpea, sorghum, and maize in soils from the experimental sites.

| Plant     | Control   | Aponkyedasoro | Nippon   | Afitatafum |
|-----------|-----------|---------------|----------|------------|
| Cowpea    | 66.65 ± 20.0 | 0.00 ± 0.00   | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Sorghum   | 7.48 ± 2.12  | 0.00 ± 0.00   | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Maize     | 45.44 ± 0.33 | 0.00 ± 0.00   | 0.00 ± 0.00 | 0.00 ± 0.00 |

Values are means; ± is standard deviation of means of three (3) replicates. Means of polluted soil significantly different from control (p < 0.05), three (3) weeks after planting.

Figure 1. The percentage means of nitrogen (N) of soils from Aponkyedasoro, Nippon and Afitatafum.

Effect of oil spilled on soil quality indicators

Nitrogen

It can be observed that the percentage means of soil from the contaminated sites (Aponkyedasoro, Nippon and Afitatafum) have low nitrogen content as compared with the control. Among the polluted soil, soil from Afitatafum showed the highest concentration of nitrogen, having means of 0.075%, followed by the soil from Nippon (0.074%) and Aponkyedasoro, respectively (0.067%) (Figure 1).

Phosphorus and potassium

It can be observed that the concentration of phosphorus was higher in the polluted soil than in the control soil. Soil from Aponkyedasoro exhibited a significantly higher concentration of phosphorus having a mean of 60.38 µg/g, followed by the soil from Nippon (having a mean of 45 µg/g) and Afitatafum (having a mean of 31.579 µg/g), respectively (Figure 2). The concentration of potassium

respectively. The three crops, however, showed a higher record of plant height in the control soils, with the highest being recorded in sorghum (46.2 cm), followed by maize (41.67 cm) with the least being recorded in cowpea (13.6 cm) (Table 4).

Moreover, maize grew on the polluted soil, but after two (2) weeks of germination, the maize plant turned brownish and was dying off, it recorded approximately zero chlorophyll content. However, there was a significantly higher chlorophyll content in the control soils, with the highest being recorded in sorghum (66.65), followed by cowpea (45.44) and maize (7.48) (Table 5).
was higher in the polluted soil samples than in the control soil. Generally, there is a significant difference between the control soil and the polluted soil samples. Soil from Afitafum recorded the highest concentration of potassium (0.583 cmol/kg) followed by the soil from Nippon having a mean concentration of 0.548 cmol/kg and soil from Aponkyedasoro having a mean of 0.523 cmol/kg, respectively (Figure 2).

**Copper, zinc and iron**

Figure 3 shows a multi axes graph representing the mean concentration of Copper (Cu), Zinc (Zn) and Iron (Fe) in the soils from Aponkyedasoro, Nippon and Afitafum. It was observed that soil from Afitafum recorded the highest concentration of Zn followed by Nippon and Aponkyedasoro, having mean values of 20.85, 9.567 µg/g and 8.800 µg/g, respectively. Soil from Aponkyedasoro and Nippon recorded nearly the same concentration of Zinc (Figure 3).

Moreover, the soils from the polluted sites contain significantly higher concentration of sodium (Na) than the control soil. Soil from Aponkyedasoro recorded the highest concentration of Na having a mean of 1.692 cmol/kg, followed by the soil from Afitafum and soil from Nippon having a mean of 1.087 and 0.087 cmol/kg, respectively. However, the concentration of Na in soil from Aponkyedasoro was significantly different from soil from Nippon and Afitafum (Figure 3).

Soil from Afitafum recorded the highest concentration of Iron (Fe) having a mean concentration of 51.291 µg/g and the control soil recorded the lowest concentration of Fe having a mean concentration of 10.86 µg/g. However, the polluted soils were significantly different from each other but there was no significant difference between the
mean concentration of Fe in soil from Nippon and the Aponkyedasoro which recorded 26.55 and 27.72 µg/g, respectively. There was a significant difference between soil from Aponkyedasoro and the control (Figure 3).

Furthermore, Aponkyedasoro recorded the highest concentration of copper (Cu) having a mean concentration of 9.86 µg/g, followed by Nippon and Afitaum having mean concentrations of 6.24 and 1.390 µg/g, respectively. Cu concentration in soil from Aponkyedasoro and Nippon was significantly different from the control soil, having a mean concentration of 9.86, 6.242 and 1.390 µg/g, respectively.

$pH$

The pH of the polluted soil was higher than that of the control. However, there was no significant difference among polluted soil in terms of pH. Soil from Afitaum recorded the highest pH of 7.6 followed by Nippon and Aponkyedasoro recording 7.4 and 7.0, respectively (Figure 4).

DISCUSSION

Soil is the most important component of the agriculture ecosystem and environmental sustainability largely depends on proper soil maintenance and management (Glaser et al., 2002). Sustainable use of soil on which agriculture depends is necessary for optimal agricultural productivity. It was observed clearly from this experiment that heavy metals and spilled engine oil in agricultural soils affect the development of plants grown on them. This is in line with the report by several researchers that, heavy metal and spilled engine oil pollution in whatever form is toxic to the plant and soil microenvironment (Gomes et al., 2013; Kayode et al., 2009; Nicholls and Mal, 2003; McGill, 1976). Generally, it was observed that there was a high significant (P< 0.01) difference between agronomic performance of crops grown on control soil and polluted soil. The level of soil nutrients in the experimental soils had a massive effect on plant germination. The nitrogen (N) level in the experimental soil was very low as compared to the control in this study. However, experimental (polluted) soil from Aponkyedasoro, Afitaum and Nippon recorded a higher level of phosphorus (P) and potassium (K) than control but yet germination of cowpea and sorghum were not recorded in this study (Table 1). Hill and De Saussure (2014), reported that, without proper aeration, mineral nutrients and other factors, plants may not be able to absorb phosphorus and potassium from the soil. The study confirmed the conclusion made from the research of Hill and De Saussure (2014), because even though experimental soil from the three polluted sites recorded a higher level of phosphorus and potassium, the presence of engine oil may have prevented proper aeration and

Figure 4. Mean concentration of Copper (Cu), Zinc (Zn) and Iron (Fe) in the soils from Aponkyedasoro, Nippon and Afitaum.
other factors that prevented cowpea and sorghum from taking up nutrient for development. Even though maize was able to germinate, it died a few weeks after later.

The presence of heavy metal in the soil had a serious effect on germination in the present study. Vwiko and Fashemi (2005), reported that one of the more important differences between new and used engine oil is the metal content. This aligns with the outcome of this study as there was a measurable presence of heavy metal (Cu, Zn, Fe, and Na) in the spilled engine oil-polluted soil from the three (3) sites. From this study, it was observed that the presence of heavy metals was approximately higher in the polluted soil than in the control. This may have accounted for the inability of cowpea and sorghum to germinate and maize to survive. Jadia and Fulekar (2009) reported that some of the direct toxic effect caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structure due to oxidative stress. This conclusion he made may be the cause of the inability of the cowpea to grow on the polluted soil. Moreover, the negative influence heavy metals, such as Zn, Cu, and Fe, have on the growth of soil microorganisms due to higher metal concentration may lead to a decrease in organic matter decomposition leading to a decline in soil nutrients. Again, enzyme activity useful for plant metabolic activities may be hampered due to heavy metal interference with the activities of soil microorganisms.

Soil from the polluted sites recorded the highest level of Zn, Cu and Fe as compared to the control. This was due to the welding activity mostly seen at the site alongside the fitting and mechanical work. Maize development in terms of girth and germination rate was low as compared with the others on this soil. Soil from Nippon was very dark and containing a higher amount of engine oil, accounting for it has the lowest ability to support maize development among the experimental soils. Kayode et al. (2009) reported that when the soil is polluted by oil, the effects range from blanketing of the soil to the displacement of pore spaces in the soil. This modifies the rate of water drainage and gaseous exchange and destroys soil texture, structure and microbial profile. The decrease in height, girth, number of leaves of the plant in experimental (polluted) soil may be due to the non-availability of adequate water, which possibly affected the nutrient uptake and mobility.

Soil pH is considered more important because it influences several soil factors affecting plant growth, such as soil microorganisms, nutrient leaching, nutrient availability, toxic elements and soil structure (Perry, 2003). Bacterial activity that releases nitrogen from organic matter and certain fertilizer is particularly affected by soil pH because bacterial operate best in the pH range of 5.5 to 7.0. It can be observed in this study that, as pH increases (pH >7) of soils from Afitafulum (pH = 7.55) and Nippon (pH=7.35), the nitrogen content of soil from Afitafulum and Nippon decreases by 0.08 and 0.07, respectively. However, as pH decrease in control soil (6.0) the nitrogen content increased 0.115%. This confirms the conclusion made by Perry (2003) and may be the cause of the soil’s inability to support plant development.

Conclusion

This study had revealed that the introduction of heavy metals and spilled engine oil into agricultural soil, adversely and severely inhibits agronomic growth and development of plants, affecting its germination rate, stem girth, height, chlorophyll content and leaves production. All the plants (cowpea and sorghum) did not germinate in the contaminated soils, except maize which grew but turned brownish and died a few weeks after germination. Soil analysis shows that there is a higher concentration of heavy metals in polluted soils and a low concentration of soil nutrients (NPKs). Heavy metals such as iron, zinc, and copper were higher in all the polluted soil as compared to the control. This concludes the concentration of heavy metals and spilled engine oil in the soil has a higher effect on plant development. Therefore, contamination of agricultural soils with heavy metals and spilled engine oil should be avoided and public awareness should be made on the detrimental effect of heavy metals and spilled engine oil pollution in our terrestrial ecosystem. Innovative and environmentally-friendly remediation strategy should be carried out on our agricultural soils that have been grossly polluted by heavy metals and spilled engine oil.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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