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Laboratory Evaluation of the Impact of Contaminants on Soil Resistivity and the Consequent Effect on Plant's Growth

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Abstract

This study is focused on investigation of the resistivity property of polluted soils and the consequent effect on the growth rate of plants. The method involves construction of an inexpensive apparatus for measuring the electrical resistivity of polluted soil in the laboratory based on application of Ohm's law. Some pollutants such as petrol, kerosene and brine were added to the soil samples and the electrical resistivity was determined. The results showed that the quantity of petrol and kerosene added to the soil were directly proportional to the resistivity of the soil while the salt concentration varied inversely with resistivity. On the other hand, the study showed that Kerosene, Petrol and Salt solution of different concentrations have an adverse effect on the growth and development of the bean plants.

Keywords

Ohm's Law, Pollutants, Resistivity, Kerosene, Petrol, Brines

1. Introduction

Soil sullying with organic and inorganic waste products is attracting attention due to toxic effects on natural vegetation, wildlife and human health [1]. Kerosene, diesel and petrol (petroleum hydrocarbons) are powerful (potent) soil organic pollutants [2] [3] [4]. Petroleum contamination could be due to spillage, leakage, discriminating disposal of petroleum products, road traffic, industrial seepage and agricultural activities [2] [5] [6] [7] [8] [9]. Petroleum of which kerosene and petrol are derivatives contain sulfur, nitrogen and oxygen in low concentrations as well as metals such as lead, nickel, sodium, calcium, copper, uranium and manganese [10] [11] [12]. It can cause chronic or acute effects on the plants. In addition to direct and indirect toxicity, the oil causes interference in the hydric relations of the plants. The toxicity leads to a reduction in the growth of the stem and the root [13].

[14] reported that toxic hydrocarbon molecules could inhibit the activities of amylase and starch phosphorylase and thereby affecting the assimilation of starch. The most common and important symptoms observed in the plants contaminated with oil and its byproducts is a degradation of chlorophyll [15] [16] [17] alterations in the stomatal mechanism [15], reduction in photosynthesis and respiration [15].

Oil spillage has been known to exhibit various deleterious effects on plants by generally retarding plant growth [18] [19] [20]; reduces aeration, by blocking air spaces between soil particles, hence creates conditions of anaerobiosis [21], and causes root stress which reduces leaf growth thereby impairing photosynthesis [15] [16] [17] [22].

Plants may be killed by oil pollution or suffer reduced growth and reproductive rates due to a combination of physical coating, altered soil chemistry and toxic effects of crude oil components [5]. Also, different heavy metals at supra optimal concentrations have been shown to inhibit various metabolic processes in plants resulting in their reduced growth and development [11] [23].

Sodium chloride (brine) when introduced in the soil could increase soil salinity and thereby affects vegetation in the surrounding area. The crop growth may be altered by the interaction between salinity and nutrients in the soil [24]. [25] reported the adverse effect of a flow in roadside salinity on irrigated agriculture.

Electrical resistivity, a physical property of the soil, can be affected by these pollutants and is determined by standard measurement of soil resistance by measuring the distance and cross sectional area through which current travels. Artificially generated electric currents are supplied to the soil and the resulting potential differences are measured. Potential difference patterns provide information in the form of subsurface heterogeneities and of their electrical properties [26]. This study is focused on investigation of the resistivity and other properties of polluted soils and the consequent effect on the growth rate of plants.

2. Method

A method is presented for constructing an inexpensive plug in apparatus for measuring the electrical resistivity of polluted soil samples in the laboratory. The principle of operation of the apparatus is based on Ohm's law. A 12v dry cell, voltmeter, ammeter was connected together with the constructed pipe and soil was introduced into the pipe as shown in **Figure 1**. Electric current is injected into soil in the pipe using two conducting metal electrodes connected to 12v battery as a power source. The potential differences ΔV between two points A and B and flow of current I in a linear line with the current electrode were measured by the voltmeter and ammeter respectively.

From Ohm's law the current, which flows through a conductor of length, L and cross sectional area S, is directly proportional to the potential difference across the ends of the conductor that is:

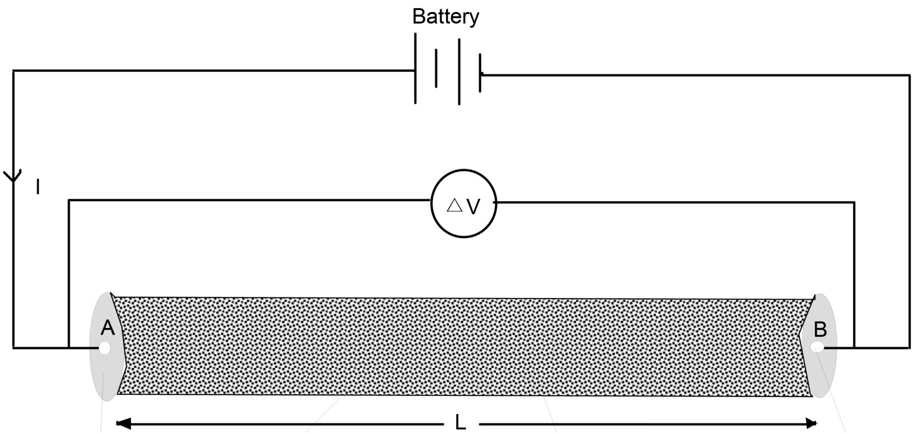

Figure 1. Experimental set up for determining the resistivity of contaminated soil in the laboratory.

$$\Delta V = IR$$

where R = resistance of the conductor (soil). It follows that

$$R = \frac{\Delta V}{I} \tag{1}$$

and R is also expressed as

$$R = \frac{\rho L}{S} = \frac{\Delta V}{I}$$

$$\rho = \left(\frac{\Delta V}{I}\right)\left(\frac{S}{L}\right) \tag{2}$$

ρ is the resistivity of the soil to be determined.

From the values of voltage (V) and current (A) measured, the resistivity is determined.

Soil was introduced into the pipes of various lengths and compacted. The initial resistivity of the soil was determined before introducing the contaminants into the soil. The contaminants introduced into the soil in the various pipes included kerosene, petrol and brine (salt solution) of different concentrations. The concentrations of brine solution are 1.0, 0.5, 0.33 and 0.10 molar. The contaminated soil samples were left for 24 hours for proper transmission into the pore spaces. Each pipe containing the soil or contaminated soil samples was connected in turns as shown in Figure 1 and current and voltage measured. The resistivity was therefore calculated using Equation (2).

The contaminants were tested on germinated beans plants to know the effective rate of growth. Six nursery bags were filled with planting soil and beans were sown in them. After germination, the plants were allowed to grow for some days. The growth rate was then measured and recorded each day for another five (5) days. Contaminants (Petrol, Kerosene and Various salt solution concentrations) were introduced into five nursery plants and one was left to serve as a control. The height of the plants from the stem above the soil level to the tip of the apical bud (terminal bud) was measured at a specified time each day. The growth rates were recorded for another five (5) consecutive days. Precaution was taken so that the contaminant was not applied directly on the plants.

3. Results and Discussion

Figure 2 showed the resistivity of the soil when different quantities of kerosene were added. It was observed that resistivity increases with volume in the three different pipes after absorption. Figure 3 equally showed the resistivity of soil to be directly proportional to the volume of petrol added. Addition of different volumes of salt solution showed inverse variation to the resistivity (see Figure 4).

Figure 5 showed that resistivity was also inversely proportional to the length of pipe used when the same volume and concentration of salt solution was added to the soil. Figure 6 showed that when the concentration of the salt solution was increased, the resistivity of the soil sample reduced.

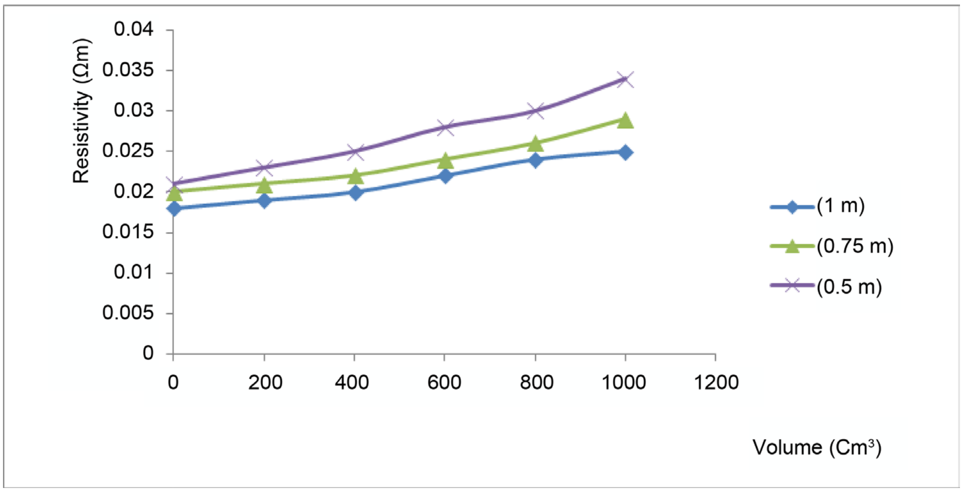

Figure 2. Graph of resistivity against the volume of kerosene added for different lengths (0.5 m, 0.75 m and 1.0 m).

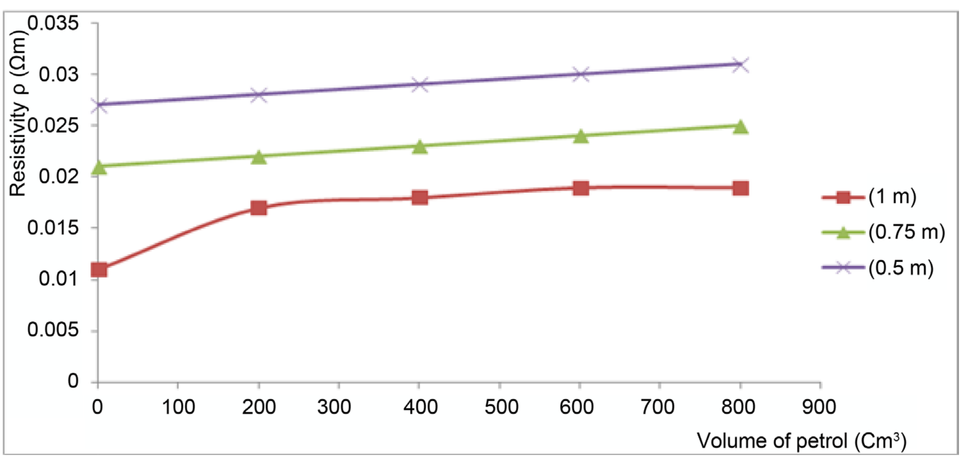

Figure 3. Graph of resistivity against the volume of petrol added for different lengths (0.5 m, 0.75 m and 1.0 m).

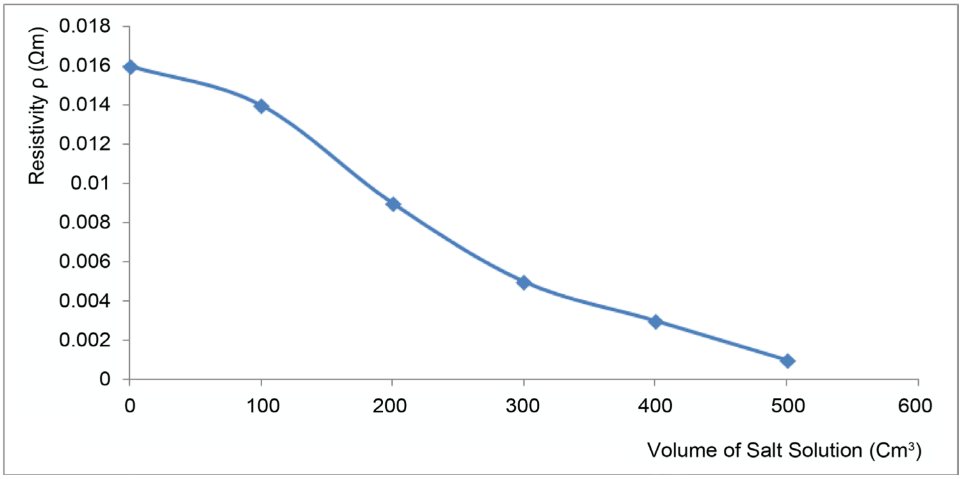

Figure 4. Adding brine solution to soil sample (at constant length of pipe) decreases its resistivity.

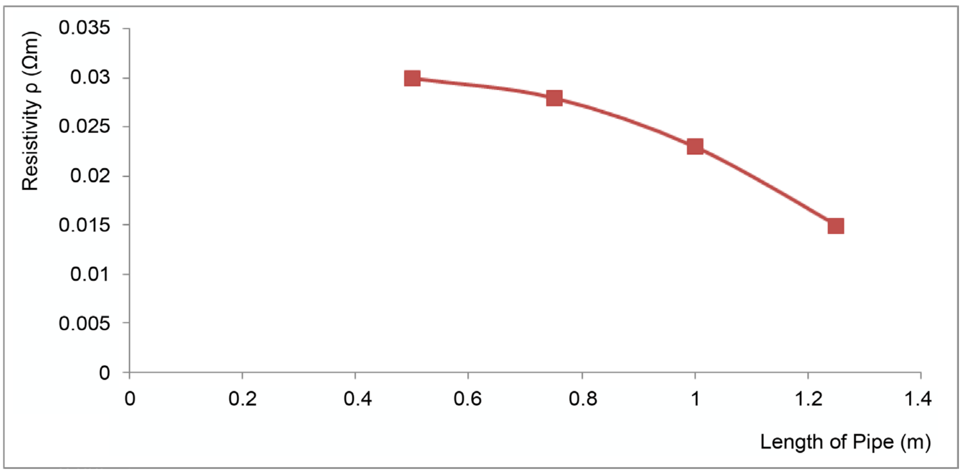

Figure 5. Graph of resistivity versus lengths (0.5 m, 0.75 m, 1.0 m and 1.25 m) of pipe at constant volume and concentration of salt solution.

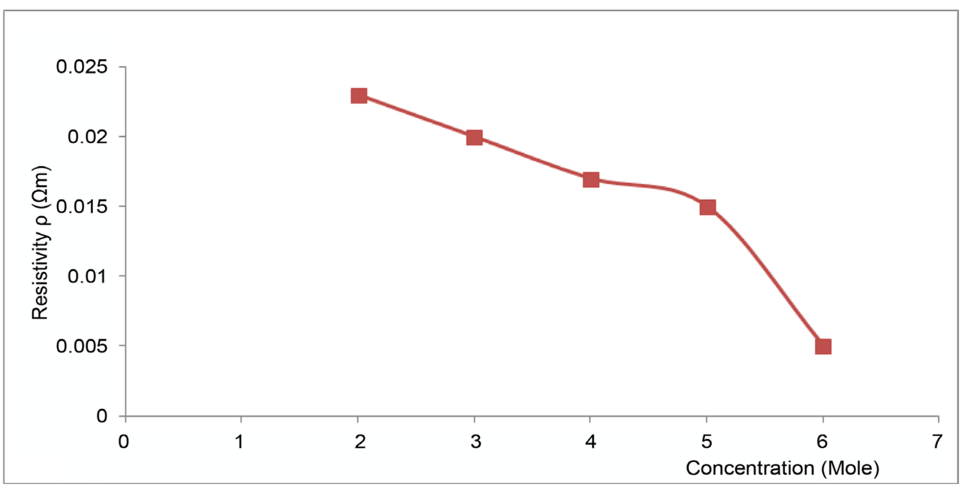

Figure 6. Resistivity is inversely proportional to the concentration of salt solution (at constant length of pipe).

In essence, pollutants such as kerosene, petrol, salt solution have effects on the resistivity of soil. From the result obtained above, it is evident that petrol and kerosene increase the resistivity of the soil while the increase in length of the tube and concentration of salt solution cause decrease in the soil resistivity, thereby increasing the soil conductivity. Generally, salt solution contains ions and when introduced into the soil increases the conductivity of the soil as is seen in **Figure 4**. Also increase in concentration of the salt solution increases the salinity of the soil, and thereby lower the resistivity, **Figure 6**.

From **Figure 7** it was also noticed that there was no growth, that is increase in height from the stem above soil level to the tip of the apical bud, in nursery bean plants D, E and F after Day 6 and by Day 11 the plants were dead. Hence, the death of the plants in nursery bean plants B, C and D with different salt concentrations was in agreement [27], that excess salinity in soil can decrease plant available water and cause plant stress.

Plants may also be killed by oil pollution or suffer reduced growth and reproductive rates due to a combination of physical coating, altered soil chemistry and toxic effects of crude oil components [5].

The nursery bean plant C was in bending position, this could be due to high concentration of salt while the plants in D, E and F later withered and died. The control A, showed a steady and normal growth in height, **Figure 7**. Results obtained from this study agreed with [28] that used engine oil as a contaminant to study its effect on plant height, stem girth and moisture content. A number of researchers had revealed that crude oil inhibits plant growth [29], reduces germination due to toxic effects on seeds [30] and leads to decrease in biomass productivity [31].

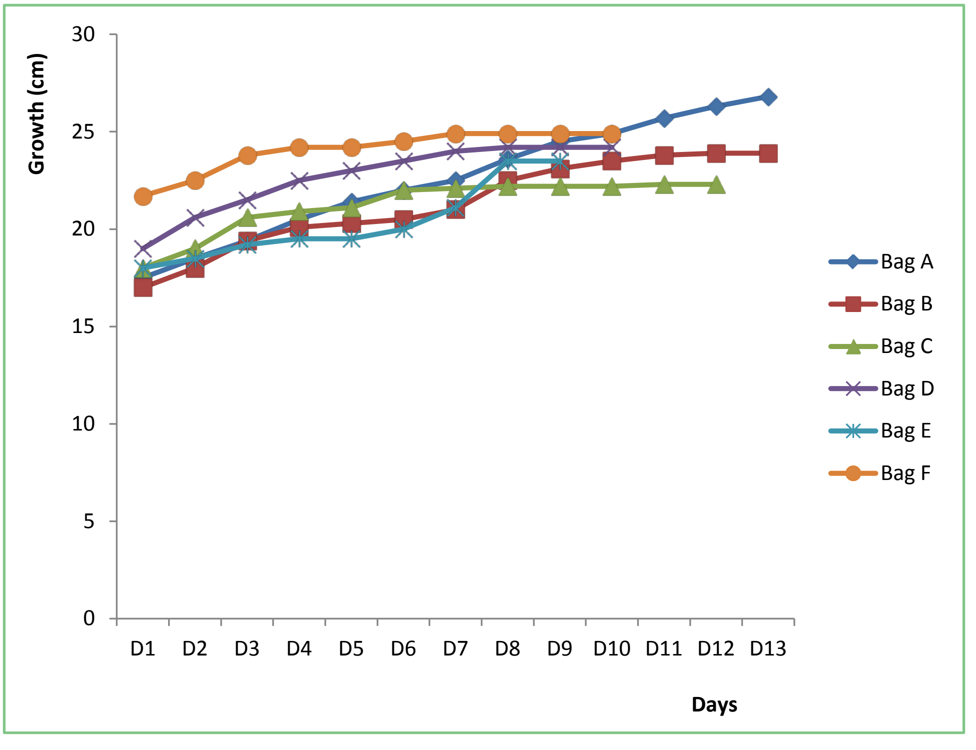

Figure 7. The graph of growth of germinated beans against days in soil of different contaminants.

4. Conclusions

The effect of the brine solution showed that, the higher the concentration of salt, the lower is the resistivity and for petrol and kerosene the higher the volume, the higher the resistivity. Length on the other hand is inversely proportional to the resistivity.

The study also showed that Kerosene, Petrol and Salt solution of different concentrations have an adverse effect on the growth and development of the plants and also on physical properties of the soil. The presence of salinity in soils and other contaminates is detrimental to plant growth.

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