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Research Article

Changes in Soil Thermal Properties and Microbial Loads of Ultisols Under Cassava Mill Effluent Discharge in Uyo, Nigeria

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Received: June 19, 2020; **Published:** July 16, 2020

Abstract

A study was conducted to examine the changes in soil thermal properties and microbial indices of Ultisols under cassava effluent discharge at varying periods. Three cassava mill sites at Uyo discharging cassava effluent within three periods: less than 5 years discharge, 10 years discharge and 15 years discharges were used. Adjacent plots to each of the sites served as control. Soil samples were collected on the surface along the discharge strides in the morning, afternoon and evening after soil temperature was measured with digital thermometer. Volumetric heat capacity, thermal conductivity and retentivity were estimated to assess the thermal properties while total bacterial count, total fungal count for mold were the parameters used to assed the microbial counts as influenced by cassava mill effluent discharge. Data were descriptively analysed and analysis of variance at 5% probability level was used to compare the mean. Among the discharge periods, volumetric heat capacity for less than 5 years (2.80 Jm^{-3}), 10 years (2.70 Jm^{-3}) and 15 years (3.00 Jm^{-3}) were significantly higher than the control (2.0 Jm^{-3}). Thermal conductivity ($Jcm^{-1}sec^{-1}$) was significantly different among the periods which followed the trend control = 15 years > 10 years > 5 years with values 2.63 = 2.59 > 2.50 > 2.45 respectively. Thermal diffusivity (cm^2sec^{-1}) was significantly low in site with less than 5 year effluent (8.71) compared to 10 years (9.46) and 15 years (11.63). Total bacterial count was significantly high in site with 15 years discharge period (6.36 $cfug^{-1}$) compared to 10 years (2.88 $cfug^{-1}$), less than 5 years (2.72 $cfug^{-1}$) and control (3.83 $cfug^{-1}$). Total fungal count for mould was significantly high in site with 15 years discharge period (4.32 $cfug^{-1}$) compared to 10 years (3.27 $cfug^{-1}$), less than 5 years (2.18 $cfug^{-1}$) and control (3.77 $cfug^{-1}$). Significantly high thermal conductivity at site receiving effluent for 15 years enhanced the population of microbes in the soil compared to other periods.

Keywords: *Fungi; Microbes; Heat; Thermal Conductivity; Retentivity; Effluent*

Introduction

Soil is the important part of the geosphere that provides support and nutrient. There are often alterations in soil chemical, physical, biological properties due to land misuse, mismanagement and indiscriminate disposal of pollutants [1,2].

Temperature is one of the main factors that determine the activity of soil microorganisms [3]. Jarvan., *et al*. [3] suggested that temperature is one of the most important factors influencing the count and occurrence of microorganisms and is also a determinant of the activity of intracellular and extracellular enzymes.

Microorganisms are involved in numerous processes controlling the flow of nutrients through specific enzymes located inside the cell [4-6] and their activity is dependent, among others, on the temperature. Soil microorganisms influence aboveground ecosystems by contributing to plant nutrition, plant health, soil structure and soil fertility [7].

The researches that have been done on the effect of cassava effluent have shown that there are always some changes in the soil properties when cassava effluents are discharged on it. Reports have also shown that the cassava effluent contains harmful cyanides, copper, mercury and nickel which have the capacity to affect native micro-biota [8]. Cyanide released from the cassava effluents are highly lethal, it is fairly mobile in the soil and destroy microbes [9].

Aim of the Study

The study aimed at assessing changes in soil thermal properties and microbial loads under cassava mill effluent discharge at varying periods.

Materials and Methods

Sampling procedure

Soils from three cassava processing mills of different processing periods (viz, 15 years, 10 years, less than 5 years) were used and a non-effluent site to serve as control. Auger and core samples were taken at surface depth of 0 - 15 cm. Sampling was done fortnightly within the hours of 6 am and 7 am, 12 pm and 1 pm and 5 pm and 6 pm. A total of 36 core and 36 auger samples were collected for routine and microbial analyses. The samples for microbial analysis were collected in sterilized polythene bags and taken in ice-packed coolers. All samples were transported to the laboratory for analyses.

Measurement and calculation of soil thermal properties

The soil temperature data and solar radiation data were used in computing the thermal properties. This was done using models as described by Edem and Edem [10].

Soil temperature measurement

Digital soil thermometer was used in the determination of the soil temperature. The thermometer was inserted into the soil and the reading was recorded before sampling. This was done three (3) times: in the morning (between 6 am and 7 am), afternoon (between 12 pm and 1 pm) and in the evening (between 5 pm and 6 pm).

Solar radiation

Solar radiation data was gotten from University of Uyo weather station for the respective sampling period.

Volumetric heat capacity

Volumetric heat capacity was calculated from the formula:

$$Cv = pc$$

Where,

p is bulk density of soil ($g.cm^{-3}$)

c is specific heat of soil ($J.g^{-1}$)

Cv is the volumetric heat capacity of soil ($J.m^{-3}$)

Thermal conductivity

Thermal conductivity was calculated from the formula:

$\lambda = (jq \times \Delta z)/(A \times dT)$

Where,

Jq is quantity of heat passing per unit time through the soil column from the surface of the soil ($J.sec^{-1}cm^{-1}$),

A is cross-sectional area of the soil (cm^2)

λ is proportionality constant, known as thermal conductivity of the soil ($J.cm^{-1}sec^{-1}$)

$dt/\Delta z$ is temperature gradient ($°C.cm^{-1}$).

Thermal diffusivity

Thermal diffusivity was calculated from the formula

$TD = \lambda/pc$

Where,

TD is Thermal diffusivity of soil (cm^2sec^{-1})

p is bulk density of soil ($g.cm^{-3}$)

c is specific heat of soil ($J.g^{-1}$)

λ is thermal conductivity of the soil ($J.cm^{-1}sec^{-1}$)

Thermal retentivity

Thermal retentivity was calculated from the formula

$TR = 1/TD$

TR is thermal retentivity ($cm^{-2}sec$)

TD is thermal diffusivity

Microbiological analysis

Serial dilution

The microbiological analysis was carried out based on the methods described by Adesemoye., *et al.* [11], Oyeleke and Manga [12]. One gram of the soil sample collected from the cassava mill effluent was serially diluted in tenfold up to 10^6 tubes. Then 1 ml from 10^6 tubes was aseptically inoculated unto already prepared plates of nutrient agar and potato dextrose agar using the pour plate method of inoculation. All plates were inverted and the nutrient agar plate (for bacteria) were incubated at 37°C. After the incubation, the total bacterial and fungal colonies on plate that contain 30 - 250 colonies were counted using a colony counter. The number of colonies on a plate were multiplied by the dilution factor to give the plate count per gram of the soil sample and recorded as $cfug^{-1}$. Example if the counts for 2 plates of the 10^6 dilution were 55 and 65, the average is 60. Therefore, the original soil sample contains 6×10^7 $cfug^{-1}$. The colonies were repeated sub-cultured unto fresh nutrient and potato dextrose agar media to obtain pure isolates.

Characterization and identification

The bacterial isolates were characterized and identified using cultural, morphological and standard tests as described by Cheesebrough [13]. The tests that were employed include Gram Stain, motility, catalase, methyl red test, voges-proskauer test, indole production, urease activity, bile solubility test, slide test, coagulase test, citrate test, carbohydrate fermentation tests, oxidase test and spore test. The fungal isolates were identified according to the method described by Oyeleke and Qkusanmi [14] based on their colour of aerial hyphase and substrate mycelium, arrangement of hyphae and conidial arrangement.

Method of data analysis

Genstat (discovery edition 3) statistical software was used to analysed the data. Analysis of variance (ANOVA) using randomized complete block design (RCBD) was employed to assess the significant of treatment effect on data collected. Significant averages were separated by LSD at 5% probability level. Correlation analysis was used to assess relationship between changes in soil properties with soil fertility indices and microbial properties

Results

Thermal properties of soils affected by CME at various periods

Thermal properties of soils affected by cassava mill effluent at various periods are shown in table 1. There was no significant difference in the volumetric heat capacity and thermal retentivity at the effluent impacted site compared to the control.

	Effluent discharge period			
	< 5 years	10 years	15 years	Control
TBC x 10^6cfu.g^{-1}				
Morning	3.10a	3.27a	5.03c	2.40c
Noon	2.18c	2.83b	6.57b	4.07b
Evening	2.87b	2.53c	7.47a	5.03a
LSD	0.28	0.21	0.71	0.77
TFCm x 10^4cfu.g^{-1}				
Morning	1.03c	4.07a	5.67a	3.00b
Noon	2.17b	2.73c	4.90b	2.97c
Evening	3.33a	3.00b	3.00c	5.33a
LSD	0.66	0.41	0.79	0.78
TFCy x 10^5cfu.g^{-1}				
Morning	4.10a	1.59c	3.00a	3.83a
Noon	1.99c	3.92b	1.83c	2.86b
Evening	2.22b	5.10a	2.27b	1.13c
LSD	0.77	1.03	0.34	0.84

Table 1: *Effect of cassava mill effluent on microbial biomass at different time.*
TBC: Total Bacterial Count; TFCm: Total Fungal Count for Mould; TFCy = Total Fungal Count for Yeast.
Means with the same letters are not significantly different (P > 0.05).

Population counts of microorganisms at different thermal conductivity on soil receiving CME

At different thermal conductivity on soil, more of bacteria were recorded in the discharge period of 15 years, more of fungal was recorded in the discharge period of 10 years and more of yeast count was recorded in the discharge period of less than 5 years.

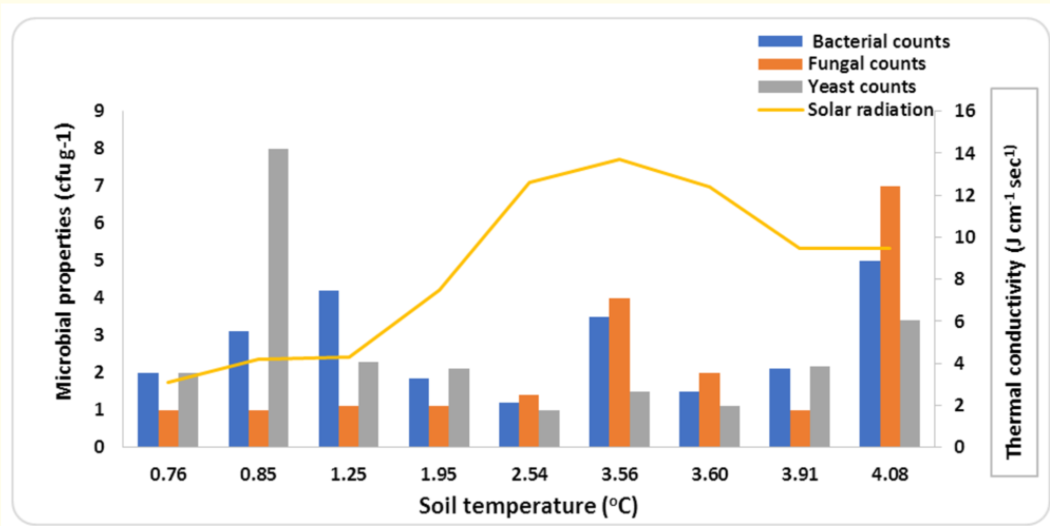

Figure 1: *Population counts of microorganisms at different thermal conductivity on soil receiving CME for less than 5 years.*

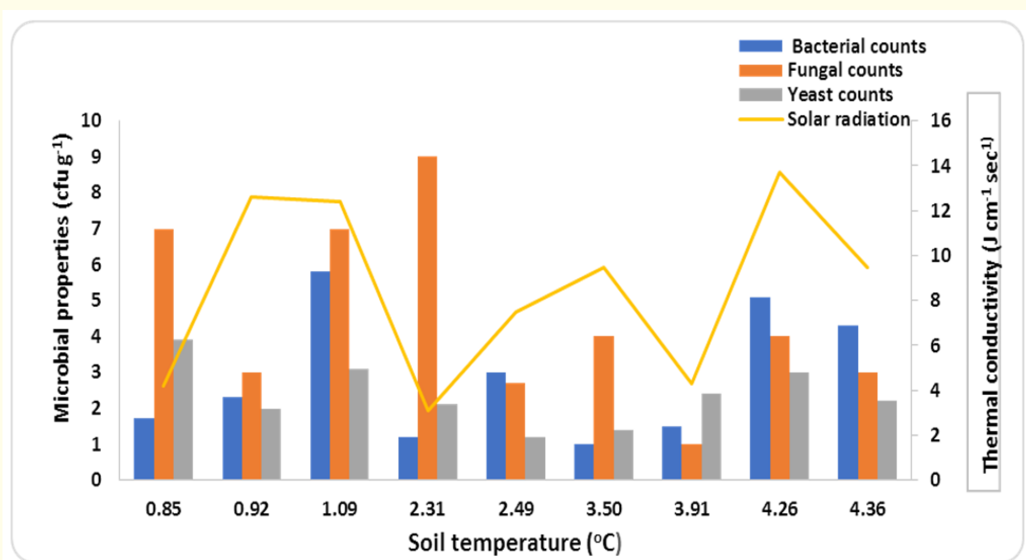

Figure 2: *Population counts of microorganisms at different thermal conductivity on soil receiving CME for 10 years.*

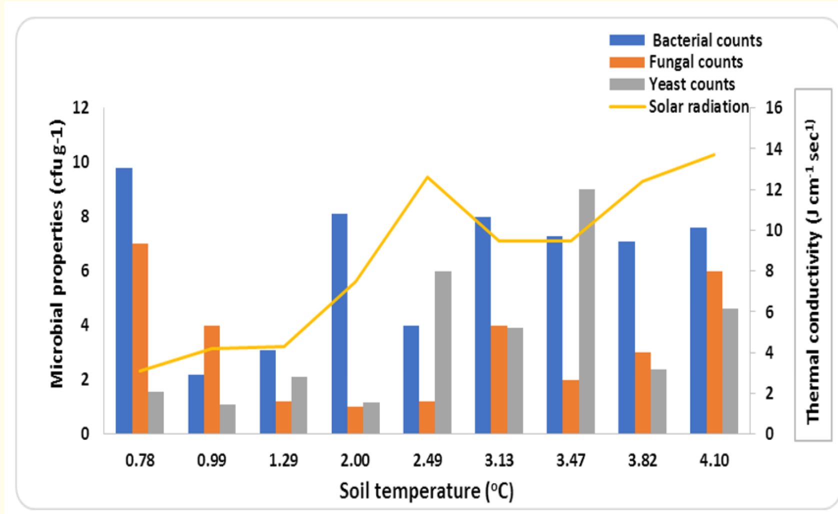

Figure 3: *Population counts of microorganisms at different thermal conductivity on soil receiving CME for 15 years.*

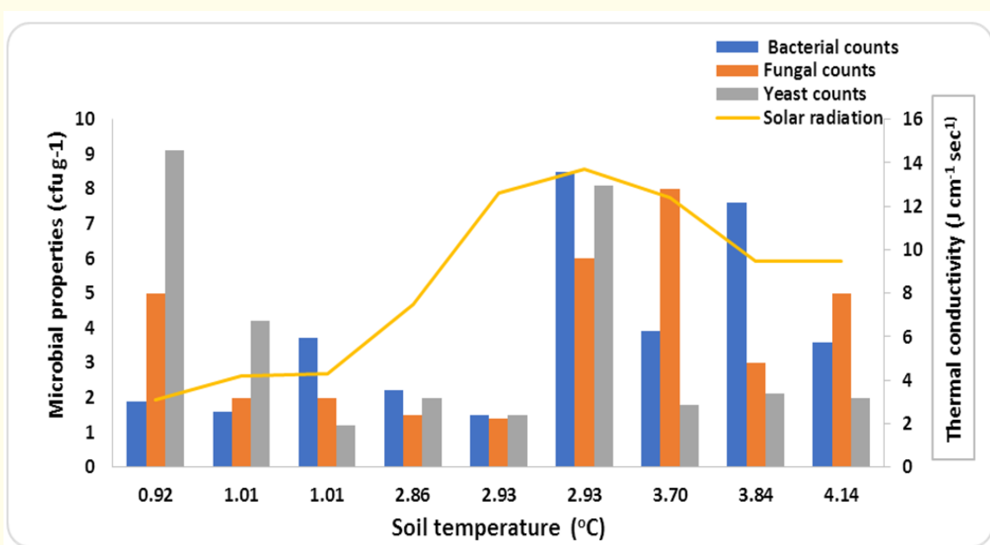

Figure 4: *Population counts of microorganisms at different thermal conductivity on soil receiving CME for control site.*

Discussion

Effects of discharge period of cassava mill effluent on thermal properties

Volumetric heat capacity was higher (3.00 $J.m^{-3}$) in discharge period of 15 years and least (2.00 $J.m^{-3}$) control. Volumetric heat capacity on average was greater in the impacted site than in the control site. This may be due to the cassava effluent in the impacted site.

Thermal conductivity was higher (2.63 J/cm/sec) in discharge period of 15 years and least (2.45 J/cm/sec) in discharge period of less than 5 years. Thermal conductivity increases with increase in discharge periods. Soils of discharge period of 15 years conducted much heat than others. This could be as a result of high sand content, organic matter and moisture content [9].

Thermal diffusivity was higher (11.63 cm^2/sec) in discharge period of 15 years and least (8.71 cm^2/sec) in discharge period of less than 5 years. As a general trend, thermal diffusivity increases with increase in discharge periods. It was seen that soils in discharge period of 15 years diffuses more heat which could be as a result of high porosity and low bulk density. Also, soils in discharge period of less than 5 years were seen to diffuse less heat and could be as a result of low porosity and high bulk density.

Thermal retentivity was higher (0.14 cm^{-2}/sec) in discharge period of less than 5 years, this was closely followed by discharge period of 10 years (0.13 cm^{-2}/sec). The least value of thermal retentivity (0.01 cm^{-2}/sec) was seen in the control site. On the average, soils of the polluted site retend much heat than soil of the control site. This could be as a result of the effluent sludge on the soil which help in the heat retention.

Effects of discharge period of cassava mill effluent on microbial properties

Total bacterial count (TBC), total fungal count for mould (TFCm) was higher in discharge period of 15 years (6.36×10^6 cfu/g, 4.52×10^4 cfu/g), closely followed by control (3.83×10^6 cfu/g, 3.77×10^4 cfu/g) and least in discharge period of less than 5 years (2.72×10^6 cfu/g, 2.18×10^4 cfu/g). However, total fungal count for yeast (TFCy) was least in discharge period of 15 years. Bacterial and fungal (mould) count was higher in discharge period of 15 years and closely followed by the control site. The high organic matter of the mill effluent may have contributed to the proliferation of these microorganisms as reported by Nwaugo., *et al* [15]. It was observed that, the microbial count decreases with decrease in discharge periods.

Effects of cassava mill effluent on microbial biomass at different time

Total bacterial count (TBC) was higher (7.47×10^6 cfu/g) in the evening at discharge period of 15 years and least (2.18×10^6 cfu/g) at noon at discharge period of less than 5 years. Total fungal count for mold was also higher (5.67×10^4 cfu/g) in the morning at discharge period of 15 years, followed by (5.33×10^4 cfu/g) in the evening at control site and least (1.03×10^4 cfu/g) in the morning at discharge period of less than 5 years. Total fungal count for yeast was more (5.10×10^5 cfu/g) in the evening period and least (1.13×10^5 cfu/g) in the evening at control site. The microbial biomass was seen to be higher in the evening period.

Enumeration of microorganisms at different thermal conductivity on soil receiving CME

It was observed that there were variations in the thermal conductivity of the soil due to variations in soil temperatures. Thermal conductivity increases the microbial counts in the effluent impacted soil than the control. This may be due to high heat retention in the effluent impacted site as heat is one of the most important factors influencing the count and occurrence of microorganisms [3]. More of bacteria were recorded in the discharge period of 15 years, more of fungal was recorded in the discharge period of 10 years and more of yeast count was recorded in the discharge period of less than 5 years.

Conclusion

It is evident from the study that there were changes in soil thermal properties and microbial population due to cassava mill effluent discharge. Cassava effluent discharge for a longer period showed increased in soil heat flow and microbial count in the soil. The effluent impacted soils retained more heat than the non-effluent soil. Soils of cassava mill effluent for longer period of showed increase in microbial population.

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Volume 6 Issue 8 August 2020