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Environmental Impacts of Different Levels of Diapers Absorbents on the Physical Fertility Status of a Typical Sandy Soil

*[1]Tangban Eji Ejor; [2]Aboh Andrew Ashieta; [3]Udama Phidel Ichuware; and [4]Ovat Innocent Ovat
[*1&2]Department of Agronomy Faculty of Agriculture and Forestry, Cross River University of Technology, Nigeria.
[3]Department of Agricultural Economics and extension, Faculty of Agriculture and Forestry, Cross River University of Technology, Nigeria.
[4]Department of Forestry and wildlife Management, Faculty of Agriculture and Forestry, Cross River University of Technology, Nigeria.
*Corresponding Author: Tangban Eji Ejor

Abstract:- The increasing prevalence of disposable diapers poses significant environmental challenges, particularly concerning their impact on soil health through improper disposal. This study investigates the effects of varying levels of diaper absorbents on the physical fertility status of a typical sandy soil, characterized by its low nutrient retention and water-holding capabilities. We conducted a controlled experiment at the Teaching and Research Farm of the University of Cross River State, Nigeria, examining six treatments with different concentrations of diaper absorbents (0g, 40g, 80g, 120g, 160g, and 200g per 10kg of soil). Key soil parameters, including pH, bulk density, total porosity, degree of saturation, and available moisture holding capacity, were analyzed over four weeks. Results indicated a significant decrease in soil pH with increasing absorbent levels, suggesting enhanced soil acidity linked to microbial activity and organic acid release. The degree of saturation increased from 12.20% in the zero absorbent treatment to 58.03% in the 200g treatment, indicating improved water retention capabilities. Additionally, bulk density decreased from 1.30 g/cm³ to 0.86 g/cm³, and total porosity increased from 51.09% to 67.42%, reflecting better soil structure and aeration with higher absorbent levels. These findings underscore the potential of diaper absorbents to modify key physical properties of sandy soils, with implications for agricultural practices and waste management strategies. Understanding these interactions is crucial for developing sustainable approaches to mitigate the environmental impacts associated with diaper disposal while preserving soil fertility and ecosystem health.

I. INTRODUCTION

The widespread use of diapers, particularly disposable varieties, has significantly contributed to the generation of municipal solid waste (MSW) worldwide. In the United States alone, an estimated 20 billion diapers are disposed of annually, posing significant environmental challenges (Geyer *et al*., 2016). The absorbent materials used in diapers, such as superabsorbent polymers (SAPs), play a crucial role in moisture retention but have raised concerns regarding their impact on soil health when improperly discarded (Miller & Tschaplinski, 2020).

Soil fertility is a fundamental aspect of agricultural productivity and ecosystem sustainability, especially in sandy soils known for their low nutrient retention and water-holding capabilities (Hillel, 2004). The introduction of foreign substances, including those from discarded diapers, can potentially alter the physical and chemical properties of soil, thus influencing its fertility status. Previous research has highlighted the potential changes in soil texture, structure, and microbial activity resulting from the incorporation of synthetic materials, which are essential for maintaining soil health and ecosystem functions (Lehmann & Rillig, 2015).

This study aims to investigate the environmental consequences of different levels of diaper absorbents on the physical fertility status of a typical sandy soil. By examining various concentrations of diaper components, we aim to elucidate their effects on key soil characteristics, such as soil pH, porosity, water retention capacity, and gravimetric moisture content. A comprehensive understanding of these interactions is crucial for developing effective waste management strategies and mitigating the environmental impacts associated with diaper disposal practices.

The research findings from this study have the potential to inform waste management policies, agricultural practices, and environmental remediation efforts aimed at preserving soil fertility and ecosystem health in regions where sandy soils are prevalent.

II. METHODOLOGY

A. Study Design

This study aims to evaluate the environmental impacts of different levels of diaper absorbents on the physical fertility status of a typical sandy soil. The experiment was conducted in a controlled environment to ensure accurate and reliable results.

B. Site Selection and Soil Sampling

➢ *Site Selection:*

The experiment was conducted in 2024 on a typical sandy soil site within the Teaching and Research farm of Department of Agronomy, Faculty of Agriculture and Forestry, University of Cross River State, Nigeria (6.8ºN, 8.20ºE). The soil of the experimental site is classified as Ultisols, Periaway *et. al.*, (1983). The area is a tropical rain forest. The mean annual rainfall ranges from 2000mm to 2500mm (CRADP, 1992).

➢ *Soil Sampling:*

Soil samples were collected from the each of the treatments and the samples were air-dried, sieved with a (2 mm) merge sieve, and taken to National Soil, Plant, Fertilizer and Water Laboratories Umudike Abia State for analysis.

C. Experimental Setup

➢ *Treatments, Replication and Application of Diaper Absorbents*

The experiment included several treatments with varying levels of diaper absorbents (0g/10kg, 40g/10kg, 80g/10kg, 120g/10kg, 160g/10kg and 200g/10kg of soil). A control treatment with no diaper absorbent was included for comparison. Each treatment was replicated five times to ensure statistical validity. Commercially available diaper absorbents was used, primarily consisting of superabsorbent polymers (SAPs). The absorbents was mixed thoroughly with the soil samples to ensure uniform distribution. Soil pH was monitored and measured weekly for four weeks in-situ using a pH probe.

D. Physical Properties: Laboratory Practices

➢ *Soil Bulk Density:*

This was determined by collecting undisturbed core samples from 1-15cm depth of soil from the different treatments using a cylindrical core. The samples were weighed and oven-dried at 105ºc to a constant weight, the mass of oven-dried soil was divided by the total volume of the core ($V_s = \pi r^2 h$ of the cylindrical core) to obtain the bulk density, Blake (1965) and Smith *et al*., (2020).

$$BD = \frac{\text{Mass of oven-dried soil (g)}}{\text{Total volume of core sample (cm}^{-3})}$$

➢ *Total Porosity:*

Soil porosity was calculated as the of total volume not occupied by soil assuming a particle density of 2.65mgm^{-3} Danielson and Sutherland (1986) and Phogat *et. al.* (2015).

$$P = 100(1 - B_d/D_p)$$

Where P = porosity
B_d = bulk density
D_p = particle density (D_p estimated to be about 2.65gcm^{-3}

➢ *Gravimetric Moisture Content:*

This was also determined mathematically by subtracting the mass of the oven-dried soil from the total sample mass dividing the mass of the oven-dried soil, Phogat *et. al.* (2015) and Hillel (1982).

$$W = (M_t - M_s)/M_s = (M_w/M_s)$$

Where W = gravimetric moisture content
M_t = total mass of sample
M_s = mass of oven-dried sample
M_w = mass of water

➢ *Degreeof Saturation; S*

This was also determined mathematically using the formula, Phogat *et. al.* (2015) and Hillel (1982).

$$S = V_w / (V_t - V_s)$$

Where S = degree of saturation
V_w = volume of water
V_t = total volume
V_s = volume of solid.

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- *Available Moisture Holding Capacity: (AMHC)*

This was done mathematically by multiplying bulk density by the gravimetric moisture content and expressing it as a percentage.

$(B_d/W) *100)$ Phogat *et. al.* (2015) and Hillel (1982).

Where: B_d = Bulk density
W = gravimetric moisture

E. Data Analysis

- *Statistical Analysis:*

Data were analyzed using ANOVA to determine the effects of diaper absorbents on soil physical fertility parameters. LSD was used to identify significant differences between treatments.

- *Software:*

Statistical analyses was performed using R software (R Core Team, 2023).

III. RESULTS AND DISCUSSION

A. Effect of Different Levels of Diapers Absorbent on Soil pH

Table 1 presents the in-situ pH values at various weeks after planting (WAP) for different treatments involving diapers absorbents. The treatments vary in the amount of absorbent added to the soil, and the pH was measured at four intervals: 1, 2, 3, and 4 WAP. The overall trend of pH values generally decreased over time across all treatments, indicating that the soil becomes more acidic as the weeks progress. This trend is consistent with natural soil processes where microbial activity and organic matter decomposition can contribute to soil acidification.

At Zero Absorbent: The pH starts at 6.74 at 1 WAP but drops to 5.02 by 4 WAP, showing a significant reduction in pH, 40g/10kg of Soil similar to the zero absorbent treatment, the pH decreases from 6.64 to 5.02, although starting at a slightly higher pH. At 80g/10kg of soil this treatment's pH also declines from 6.32 to 4.80, indicating a notable drop, particularly by the 4th week. At 120g/10kg of soil this treatment shows a more pronounced acidity with initial pH values dropping from 5.20 to 4.62, reflecting a significant change while at 160g/10kg of soil and 200g/10kg of Soil: Both treatments start with similar or lower pH levels compared to the lower absorbent treatments, but they show a slight recovery in pH by 4 WAP (5.28 for 160g and 4.88 for 200g).

- *Statistical Significance:*

Treatments with the same letter (e.g., "a" or "b") in a column are not significantly different at the $p \leq 0.05$ level. This indicates that while there is a clear trend of decreasing pH with increasing absorbent levels, only certain treatments (particularly 120g and above) statistically differ in pH values.

- *Impact of Absorbents:*

The results suggest that higher levels of diaper absorbents contribute to a decrease in soil pH, potentially due to the release of organic acids from the absorbents or increased microbial activity that may leach nutrients and further acidify the soil. Understanding how different levels of absorbent materials affect soil pH can guide agricultural practices. If the goal is to maintain a neutral pH for crops that prefer less acidic conditions, it would be prudent to limit the use of higher levels of absorbents. Long-term studies could provide insights into how these changes in pH affect nutrient availability and plant growth over time, as well as the overall fertility status of the soil, as indicated in Table 2. In summary, the data reveals significant variations in soil pH influenced by diaper absorbent levels, with implications for soil management and crop production strategies.

B. Effects of Different Levels of Diapers Absorbents on Soil Physical Fertility Status.

Table 2 presents the effects of different levels of diaper absorbents on the physical fertility status of sandy soil, measured by parameters such as degree of saturation, bulk density, total porosity, and soil moisture content (GMC and AMHC).

- *Degree of Saturation:*

There is a clear increase in the degree of saturation with higher levels of diaper absorbent. The zero absorbent treatment has the lowest saturation (12.20%), while the 200g treatment achieves the highest saturation (58.03%). This suggests that the absorbents enhance the soil's ability to retain water.

- *Bulk Density:*

Bulk density decreases as the absorbent levels increase. The zero absorbent treatment has the highest bulk density ($1.30\ g/cm^3$), indicating a denser and potentially less aerated soil structure. Conversely, the 200g treatment has the lowest bulk density ($0.86\ g/cm^3$), which may improve root penetration and aeration.

- *Total Porosity:*

Total porosity increases with higher absorbent levels, moving from 51.09% in the zero absorbent treatment to 67.42% in the 200g treatment. Higher porosity is favorable as it enhances the soil's capacity to hold air and water, which are crucial for plant growth.

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➢ *GMC and AMHC:*

Both gravimetric moisture content (GMC) and available moisture holding capacity (AMHC) improve significantly with increasing absorbent levels. For the zero absorbent treatment, GMC is only 0.12, while it rises to 0.58 for the 200g treatment, indicating better moisture retention capability. AMHC also reflects this trend, increasing from 9.43 for zero absorbent to 69.03 for the highest absorbent treatment.

C. Environmental Implications:

The findings suggest that using diaper absorbents can significantly improve sandy soil properties. Enhanced water retention (higher degree of saturation and GMC) can reduce irrigation needs, which is particularly beneficial in arid regions. This could lead to more sustainable agricultural practices by promoting efficient water use.

➢ *Impact on Plant Growth:*

Improved soil porosity and lower bulk density are vital for root development and nutrient uptake. Plants growing in soils with higher porosity are likely to experience better aeration and root expansion, leading to healthier growth. The increase in moisture retention capacity also supports plant growth, especially during dry periods.

D. Management Practices:

Incorporating diaper absorbents into sandy soils could serve as a practical strategy for enhancing soil fertility and structure, thereby improving plant productivity. This approach could be particularly useful in rehabilitating degraded lands or improving crop yields in sandy regions when pH is adequately managed.

The results from Table 2 indicate that the addition of diaper absorbents positively affects the physical properties of sandy soils, enhancing their suitability for agricultural use. These improvements could lead to better environmental management practices and increased agricultural productivity, highlighting the potential benefits of recycled materials in soil improvement strategies. Further research into the long-term effects and economic viability of using such absorbents in various soil types would be beneficial.

IV. SUMMARY

The study "Environmental impacts of different levels of diapers absorbents on the physical fertility status of a typical sandy soil" investigates how varying concentrations of diaper absorbents affect the physical properties of sandy soil. Conducted at the University of Cross River State, Nigeria, the research examines treatments with diaper absorbents ranging from 0g to 200g per 10kg of soil. Over four weeks, key soil parameters such as pH, bulk density, porosity, saturation, and moisture capacity were measured.

Results show a significant decrease in soil pH with higher absorbent levels, indicating increased acidity due to microbial activity. Water retention improved, as saturation increased from 12.20% to 58.03%. Bulk density decreased, and porosity increased, reflecting better soil structure. These findings suggest that diaper absorbents can enhance the physical properties of sandy soils, offering insights for agricultural practices and waste management strategies to mitigate environmental impacts.

V. CONCLUSION

This study provides critical insights into the environmental impacts of diaper absorbents on the physical fertility status of sandy soils. The findings indicate that the incorporation of superabsorbent polymers from diapers significantly alters soil properties, with notable effects on pH, saturation, bulk density, and total porosity. The results reveal a clear trend of decreasing soil pH with increasing levels of diaper absorbents, suggesting potential acidification due to microbial activity and organic acid release. Such changes in soil acidity can have profound implications for nutrient availability and crop productivity, particularly in sandy soils that are already challenged by low nutrient and water retention capacities.

Moreover, higher levels of diaper absorbents enhanced the soil's water retention capabilities, as evidenced by increased degrees of saturation and total porosity alongside decreased bulk density. These alterations may improve soil aeration and root penetration, which are beneficial for plant growth. In conclusion, while diaper absorbents can enhance certain physical properties of sandy soils, their long-term application poses risks of soil acidification and nutrient leaching. Therefore, it is essential for agricultural practices and waste management policies to consider these findings in order to mitigate the environmental impacts associated with diaper disposal. Further research is recommended to explore the long-term effects of diaper absorbents on soil health and ecosystem sustainability.

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Table 1. In-Situ pH Values as Affected by Different Levels of Diapers Absorbents at 1 - 4 WAP

Treatment	pH @ 1WAP	pH @ 2WAP	pH @ 3WAP	pH @ 4WAP
Zero Absorbent	6.74a	5.56a	5.58a	5.02a
40g/10kg soil	6.64a	5.12a	5.08a	5.02a
80g/10kg soil	6.32a	4.94a	4.92a	4.80a
120g/10kg soil	5.20b	4.84a	4.76a	4.62a
160g/10kg soil	5.34b	4.92a	5.00a	5.28a
200g/10kg soil	5.34b	4.84a	4.88a	4.88a
SE	**0.32**	**0.34**	**0.29**	**0.25**

Means with the same letter in a column for each factor are not significantly different ($P \leq 0.05$)
SE = Standard Error

Table 2. Effects of Different Levels of Diapers Absorbents on Physical Fertility Status of a Typical Sandy Soil.

Treatment	Degree of Saturation	Bulk Density	Total Porosity	GMC	AMHC
Absorbent 0g	12.20d	1.30a	51.09d	0.12d	9.43d
Absorbent 40g	24.82cd	1.16ab	56.30cd	0.24cd	21.92cd
Absorbent 80g	36.99bc	1.04bc	60.67bc	0.37bc	36.76bc
Absorbent 120g	45.68ab	0.92cd	65.08ab	0.46ab	51.95ab

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Absorbent 160g	45.80ab	0.91cd	65.51ab	0.46ab	53.50ab
Absorbent 200g	58.03a	0.86d	67.42a	0.58a	69.03a
LSD	**16.65**	**0.15**	**5.45**	**0.17**	**24.71**

Means with the same letter in a column for each factor are not significantly different ($P \leq 0.05$)