Journal of Biodiversity and Environmental Research
January, 2025 Editions
www.ssaapublications.com

JBER
Vol.7, No.4, E-ISSN 3027-1916
P-ISSN 3026-9466
Sahara African Academic

THE EFFECT OF SEWAGE EFFLUENCE ON THE PERMEABILITY OF SOIL

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DOI: https://doi.org/10.70382/sjber.v7i4.011

Abstract

Sewage is water-carried wastes, in either solution or suspension that flow away from a community. Soil permeability is the ability of the soil to pass water under saturated conditions. This study addressed a critical environmental concern surrounding the potential impact of sewage discharge on soil permeability with a view to providing insights into the potential threats posed by sewage effluent on soil ecosystems, informing sustainable wastewater management practices and contributing to the broader discourse on environmental protection and resource conservation. This study therefore aimed to investigate the effects of sewage effluence on the permeability of soil. The samples collected for this study were soil, test specimen (laterite) and sewage effluence (collected from excavating up to depth of one meter below the ground surface in Federal polytechnic Offa and the disposal site at Owode market in abattoir, Offa, Kwara State). The lateritic soil samples were evaluated using standard analytical methods for moisture content, particle size analysis, Atterberg limit, liquid limit, plastic limit, plasticity index, compaction test and permeability test. The results of the varying analysis conducted on the lateritic soil showed that the lateritic soil has high water retention capacity, good particle size distribution which are suitable for use in road construction, plasticity index of the soil reduce when

mixed with the clean water but increased when mixed with the waste water while the permeability of the soil sample decreased with increase in the percentage of sewage effluent used for the test. The study therefore concluded that permeability of any soil sample depended on the void ratio of the soil since water passed through only the voids present in a soil sample, the effect of pollution on permeability of soil should depend on the effect of the pollution on the void ratio of the sample, permeability of the soil sample was hindered by pollution. The study recommended that the research should be carried out using pollution of higher pollutant strength.

Key words; Sewage, Waste, Pollution, Soil, Permeability, Construction.

Introduction

Soils are permeable materials because of the presence of interconnected voids that permit the flow of fluids from locations of high energy to locations of low energy. Proper measurement or evaluation of soil permeability is required for calculating the seepage under hydraulic structures and water quantities during dewatering activities. Soil permeability is affected by several factors including voids ratio, distribution of inter-granular pores, and degree of saturation (Elhakim, 2016). Soil porosity is a functional space that connects the soil body with its environment (Lal and Shukla, 2004). Soil pores play an important role in determining the physical, chemical and biological properties of soil (Munkholm *et al.*, 2012; Oorts *et al.*, 2007; Pagliai *et al.*, 2004; Sleutel *et al.*, 2012; Smucker *et al.*, 2007).

Soil physical and chemical processes that do not occur inside the particles or on the soil surface occur in the soil pore spaces (spaces between particles). It is in the soil pore space that air, water, and biological waste products and nutrients are transmitted from one place to another in the soil (Mawardi, 2011). Pore characteristics describe the number, size, distribution, continuity and stability of soil pores. Soil porosity is influenced by soil texture, structure, and organic matter content. In sandy soils, soil porosity is dominated by macro pores which function as water traffic so that infiltration increases. Whereas in clay soils, micro

pores play a more important role and the water conductivity is low so that infiltration decreases (Suharyatun *et al.*, 2019).

The soil compaction can be defined as "the process by which the soil grains are rearranged to decrease void space and bring them into closer contact with one another, thereby, increasing the bulk density". So, the soil compaction involves the changes in physical properties of the soil (bulk density and soil porosity) and these modified physical parameters of the soil are determinants of the influence of the soil compaction on chemical properties of the soil, soil fauna, and diversity and plant growth (Nawaz *et al.*, 2013). The soil compaction is the physical form of soil degradation that changes the soil structure and influences the soil productivity (Mueller *et al.*, 2010). Unlike salinity, water logging or the soil erosion that can be remarked from the soil surface, the soil compaction causes a hidden degradation of the soil structure that is difficult to locate and rationalize (McGarry and Sharp 2003).

Soil permeability is the ability of the soil to pass water under saturated conditions (Dariah *et al.*, 2006). Quantitatively, soil permeability/hydraulic conductivity is the velocity of movement of a liquid in a porous medium and is defined as the velocity of water passing through the soil in a certain period of time expressed in centimeters per hour. Soil permeability is affected by the texture, structure and porosity of the soil. Permeability can affect the level of soil fertility because it includes how water, organic matter, mineral matter, air, and other particles are carried with the water into the soil (Rohmat, 2009).

Sewage is water-carried wastes, in either solution or suspension that flow away from a community. It is also known as waste water flows or used water supply of the community. It is more than 99.9% pure water characterized by its volume or rate of flow, its physical condition, its chemical constituents, and the bacteriological organisms that it contains. Depending on their origin, wastewater can be classed as sanitary, commercial, industrial, or surface runoff. The spent water from residences and institutions, carrying body wastes, washing water, food preparation wastes, laundry wastes, and other waste products of normal living, are classed as domestic or sanitary sewage. Liquid-carried wastes from stores and service establishments serving the immediate community, termed

commercial wastes, are included in the sanitary or domestic sewage category if their characteristics are similar to household flows (Ibiam and Igewnyi, 2012). Waste-water generally is generated from water usage by residences, industrial and commercial establishments and agro-industrial activities as well along with ground, surface and storm water. However, its composition depends on the source generating it. In the urbanized, developing world, it is learnt that at least 2.6 billion people lack access to safe drinking water and proper sanitation (Rijsberman, 2006). Supplying clean and affordable water to fulfill the human needs of the ever-growing population is one of the greatest challenges of the 21st century. According to the United Nations World Water Development Report, a total of 22% global water is withdrawn and consumed by Industries; that varies from 59% in high income countries to 8% in low-income countries. Globally, about 70% of fresh water withdrawals is consumed for agriculture (FAO, 2002). However, only 24% of the wastewater generated from households and industries is treated before its disposal into rivers and reuse in agriculture (Minhas and Samra, 2003).

Materials and Method

Methodology

Two different samples were collected for this research. The samples are the soil, the test specimen and the sewage effluent, which serves as the pollutant. The soil sample was collected by excavating up to depth of one meter below the ground surface, in Federal polytechnic Offa, mini campus, along boys' hostel Offa, Kwara State. This resulted in the collection of a lateritic soil sample. This exercise was facilitated by using undisturbed method. The collected soil sample was then conveyed to the civil engineering soil laboratory, using a sack. It was then sprayed properly for air-drying, where it was left for up to 14 days. The pollutant, sewage effluent, was collected from the disposal site at Owode market in abattoir, Offa, Kwara State. It was done by the use of 5 liters keg, and was conveyed to the laboratory, immediately.

Materials

The materials used for this study were,

1. Wastewater

2. Lateritic soil

Determination of the natural moisture content of soil sample

The moisture content of a soil sample is an indispensable parameter in the evaluation of the permeability of the sample. This parameter is also of vital role in the classification and grouping of natural soils.

To evaluate or determine the moisture content of the air-dried sample, the oven-drying method was employed. The accuracy of the moisture content obtained for soils using oven-drying method is greatly dependent on the oven drying temperature. A standard oven drying temperature of $110+5^{o}$ c was used.

Procedure

The procedure employed in the test is in accordance with the provision of BS 1377: part 2: 1990:3.2. The procedure is as outlined below,

Two moisture content cans were cleaned, dried and weighed to the nearest 0.1g, using a triple beam balance, it was ensured that the balance is teared to the initial reading of zero.

i. About 30g each of the air-dried soil sample was placed in the moisture content cans. The weight of the moisture content cans with their contents was taken again.
ii. With the moisture content cans open and the lids attached under, they were placed in the soil oven. These were reweighed after 24hours.
iii. About 3kg of the sample is tied each in five separate sacks to retain the moisture content.

Compaction test

The major aim of compaction test was to determine the moisture-density relationship of a given soil sample. Using the compaction test process, various values of moisture ranging from 6%, 8%, 10% and 12% was used to compact the soil and the corresponding values of the dry density were obtained.

At a certain value of moisture content (optimum value) the value of the dry density is maximum. Beyond this optimum moisture content, the soil fails and hence, the soil begins to lose its compatibility and thus the soil particles will start

segregating or moving away from one another. This test will enable the determination of the quality of water to mix the soil for permeability test.

Apparatus

a. Proctor mould
b. Measuring cylinder.
c. Soil tray
d. 4.5kg rammer.
e. Weighing balance.
f. Spatula.

Procedure

The procedure for the test was followed in strict adherence to the provisions and stipulations of the code BS 1377, part 4, 1990. clause 3.3-3.6. The procedure is as described below.

The weight of an empty proctor mould was measured and recorded. 6kg of air-dried was collected in soil tray. The lumps were crushed with a rubber pistle.

The soil was then divided into four parts. Each layer was put in the mould and rammed with the rammer by giving 25 blows. The ramming of each layer was completed and the extension was removed.

The soil level was trimmed with a straight edge. The mould was properly cleaned and then weighed on a balance and the weight recorded. Soil sample was collected at the top and bottom of the mould for moisture content determination.

The above process was repeated with the quality of water increased each time by 2% and soil samples were collected at the top and bottom of the mould, each time for moisture content determination. At each stage, the weight of the mould with wet soil was measured and recorded.

The moisture content of the samples collected at the top and bottom was determined by drying in a soil oven for 24 hours.

The entire process described above was repeated several times mixing the soil with a mixture of sewage effluent and water, combined in a particular proportion. The ratio of sewage effluent to water is varied severally, and the process repeated to determine the effect of the quantity of pollution in the water-sewage mixture

on the moisture content-dry density relationship. In each case the optimum moisture content (OMC) and the maximum dry density were evaluated and recorded

The permeability test

As defined earlier, permeability is the term used to describe the property of a soil, which permits flow of water (or any other liquid) through it. In other words, the permeability of a soil is the ease with which water can flow through it.

Generally, water flows through fine-grained soil at a much slower rate than coarse material.

The various types of apparatus, which are used in soil laboratories for determining coefficient of permeability of soils, are called permeameters. They are of two basic designs, the constant head type and the variable head type.

The major aim of this test is to measure the rate of seepage through a given soil sample, using the falling head method.

The test also leads to determination of how this property is affected by pollution.

Apparatus

The following apparatus were used to carry out the test,

a. Falling head permeability apparatus (fig 3.1).
b. Permeability port.
c. Soil cutter
d. 2.5kg rammer
e. Weighing balance.
f. Bucket
g. Stop watch
h. Proctor mould

Procedure

The procedure for this test was followed in strict adherence to the provisions and stipulations of the code BS1377-5 1990 clause 5. The procedure is as described below.

i. The compaction test was first carried out and the optimum moisture content (OMC) and maximum dry density evaluated. These parameters were used to evaluate the quantity of water needed for a one-point compaction.
ii. The quantity of water obtained was used to mix the soil sample after which the sample was compacted and then cut with a soil cutter.
iii. The sample and the cutter placed in the permeability pot (proctor mould), and fixed the permeability apparatus.
iv. The test was run by allowing water to flow from the transparent reservoir up to the standpipe.

This was achieved by opening the clip when the water reached a desired height, the clip A was locked and a stop watch was set to ensure that the flow last for exactly 30secs, when clip B was opened. The height of water before flow was noted and recorded.

The permeability of the sample was then evaluated for each change in height after 30secs from, $k = 2.30al\_x \log_{10} [h_1/h_2]$

The entire process described above was repeated of varying pollutal strength. The implication of mixing the soil with sewage of varying pollutal strength is to know the effect of sewage effluent on the permeability of soil.

Result and Discussion

Results

Table 1: The natural moisture content of the soil sample

Observation	Trials		
	1	**2**	**3**
Weight of sample + can (gm)	57.0	57.0	**57.0**
Weight of oven dried soil+ can (gm)	49.0	50.0	**49.0**
Weight of empty can (gm)	7.0	7.0	**7.0**
Weight of moisture (gm)	8.0	7.0	**8.0**
Weight. of dry soil (gm)	42.0	43.0	**42.0**
Moisture content %	19.05	16.28	**19.05**
Average moisture content %	**18.13**		

From the result of the test, the average moisture content was computed as 18.13%. This high value of natural moisture content after air dried for 14 days indicates that the lateritic soil has high water retention capacity.

Table 2: Result of sieve analysis for Lateritic soil

Sieve size	Weight of sieve (g)	Weight Retained (g)	Cumulative weight retained	Cumulative percentage retained	Cumulative percentage passing
19.0	528	0	0	0	100
13.2	447	457	10	1	99
12.50	630	638	8	1.8	98.2
10.00	621	647	26	4.4	95.6
9.50	542	546	4	4.8	95.2
6.30	535	620	85	13.3	86.7
4.75	672	544	72	20.5	79.5
2.36	544	754	210	41.5	58.5
2.0	422	470	48	46.3	53.7
300µm	386	441	55	51.8	48.2
150µm	415	864	450	96.8	3.2
63µm	375	398	24	99.2	0.8
Pan	204	212	1000	100	0

The particle size distribution analysis shows the range of particle sizes present in the soil according to the Federal ministry of work and housing specification requirement, for a sample to be used for road construction, the percentage by weight passing the number 200 sieve shall be less than but not greater than 35% sequel to the above, the sample under review were good samples because percentage by weight passing sieve number 200 not exceed 35%.

Table 3: Result for overall permeability test

% of sewage effluent	0%	25%	50%	75%	100%
K*10^{-4} (cm/s)	**7.4**	**6.8**	**5.52**	**5.36**	**5.24**

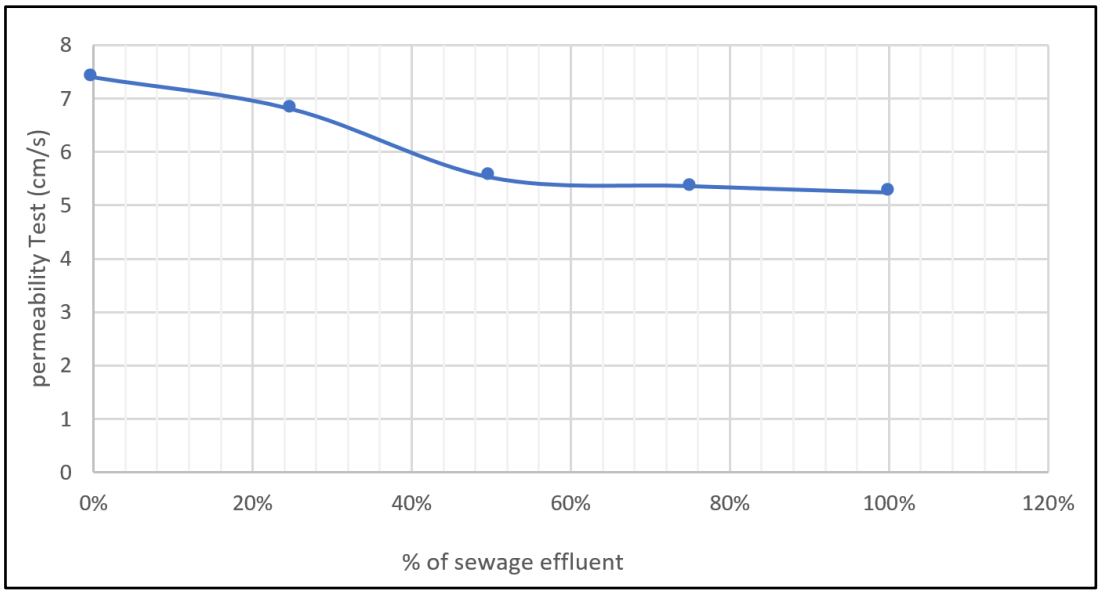

Figure 1: Result for overall permeability test

The effect of pollution on permeability, and other engineering properties of soil, is of great concern to every practicing civil engineer. These effects enable civil engineers to know the suitability of soil for some civil engineering works, and to obtain soils of desired properties through additives.

The graph of permeability against the percentage of sewage effluent is a straight line sloping down from left to right.

This results from the fact that the permeability of the soil sample decreases with increase in the percentage of sewage effluent used for the test. In other words, the permeability is inversely proportional to the amount of sewage effluent used in the test.

Conclusion

The conclusions for this study are:

1. Permeability of any soil sample depends on the void ratio of the soil, since water passes through only the voids present in a soil sample. The effect of pollution on permeability of soil should depend on the effect of the pollution on the void ratio of the sample.
2. From the research carried out, the values of the permeability obtained, and the shape of the graph showed that the permeability of the soil sample is

hindered by pollution. This believe is as a result of the sewage effluent containing some microscopic solid particles. These particles move in between the soil particles and plug up pore passages. At the same time, the rate at which water passes through these pores is reduced

References

Dariah, A., Yuzrial, and Mazwar. M., (2006). *Penetapan konduktivitas hidrolik tanah dalam keadaan jenuh: Metode Laboratorium. In Kurnia, U., Agus, F., Adimihardja, A., and Daria, A. (editors). Sifat Fisik Tanah dan Metode Mnalisisnya. Balai Besar Litbang Sumberdaya Lahan Pertanian*, Kementerian Pertanian, Jakarta: 172-180.

Elhakim, A. F., (2016). *Estimation of soil permeability*. Alexandria Engineering Journal, 55, 2631 – 2638

Lal, R., and Shukla, M. (2004). Principle of Soil Physics. CRC Press, Boca Raton.

lbiam O. F. A., and Igewnyi I. O., (2012). Sewage management and its benefits to man. *International Research Journal of Biotechnology*, 3(10): 174-189

Mawardi, M. (2011). Asas irigasi dan konservasi air (Yogyakarta). Bursa Ilmu.// imt.jogjaprov.go.id/simperpus/index.php?p=show_detailandid=5327andkeywords=

McGarry, D., and Sharp, G., (2003). A rapid, immediate, farmer-usable method of assessing soil structure condition to support conservation agriculture. Conservation agriculture: environment, farmers experiences, innovations, socio-economy, policy, p. 375

Minhas, P. S. and Samra, J. S. (2003). "Quality Assessment of water resources in Indo-Gangetic basin part in India",Central Soil Salinity Research Institute, Karnal, India, p68

Mueller L, Schindler U, Mirschel W, Shepherd TG, Ball BC, Helming K, Rogasik J, Eulenstein F, and Wiggering, H., (2010) Assessing the productivity function of soils. A review. *Agron Sustain Dev*., 30:601–614

Munkholm, L.J., Heck, R.J., and Deen, B. (2012). Soil pore characteristics assessed from Xray micro-CT derived images and correlations to soil friability. *Geoderma*, 181– 182, 22–29

Nawaz, M. F., Bourrié, G., znd Trolard, F., (2013). Soil compaction impact and modelling. A review. Agron. *Sustain. Dev*., 33:291–309

Oorts, K., Bossuyt, H., Labreuche, J., Merckx, R., and Nicolardot, B. (2007). Carbon and nitrogen stocks in relation to organic matter fractions, aggregation and pore size distribution in no-tillage and conventional tillage in northern France. *European Journal of Soil Science*, 58(1), 248–259.

Pagliai, M., Vignozzi, N., and Pellegrini, S., (2004). Soil structure and the effect of management practices*. Soil and Tillage Research*, 79(2), 131–143.

Rijsberman, F. R., (2006). "Water scarcity: fact orfiction?" *Agricultural water management*, 80(1): 5-22.

Rohmat, A., (2009). Tipikal Kuantitas Infiltrasi Menurut Karakteristik Lahan. Erlangga, Jakarta.

Sleutel, S., Bouckaert, L., Buchan, D., Van Loo, D., Cornelis, W.M., and Sanga, H.G., (2012). Manipulation of the soil pore and microbial community structure in soil mesocosm incubation studies. *Soil Biology and Biochemistry*, 45, 40–48

Smucker, A.J.M., Park, E.-J., Dorner, J., and Horn, R. (2007). Soil micropore development and contributions to soluble carbon transport within macroaggregates. *Vadose Zone Journal*, 6(2), 282–290.

Suharyatun, S., Rahmawati, W., and Sugianti, C., (2019). Jaringan syaraf tiruan untuk pendugaan porositas tanah. *Seminar Nasional Lahan Suboptimal*, 1, 424-429.