Removal of Nitrate in Landfill Leachate using Jute Fabric and Amended River Sand

J.C. Agunwamba(1), O.C. Amadi(2)

Department of Civil Engineering, University of Nigeria, Nsukka, Enugu State, Nigeria.

Abstract

Leachates emanating from landfills had been the major source of groundwater pollution. In order to curb groundwater pollution, liners should be incorporated in the design of Leachate Collection System (LCS). Jute fabric was chosen as a landfill liner because of its inherent properties such as: eco-friendly, durable, renewable, affordable, etc. Nitrate was the only landfill leachate pollutant studied because of its long term effect on the environment. Nitrate was found to be in very high concentration many decades after closure of landfills. From the laboratory study presented herein, it was observed that LCS that had jute fabrics as liners had lower concentration of nitrate when compared with LCS without liners. Further investigation revealed that increasing number of liners contained in LCS decreases the concentration of nitrate contained in the effluent.

Keywords — *Liners, Nitrate, LCS, Leachate, Amended River Sand.*

I. INTRODUCTION

Nitrate is a wide spread contaminant of ground and surface waters. It causes a condition known as Methemoglobinemia also called blue baby syndrome in infants [1]. High level of Nitrates in human body has also been attributed to cause Cancer [2]. Heavy metals and the xenobiotic organic compounds have been reported to have adverse effects on man. They cause kidney and liver failures (e.g. Mercury, Lead, Cadmium, and Copper) and also affect the skin, bones and tooth (e.g. Nickel, Cadmium, Copper, etc) [3]. Also, hazardous chemicals from landfills have been attributed to be the cause of cancers and increasing frequencies of chromosomal changes [4] and [5].

In order to mitigate the adverse effects associated with uncontrolled landfills, scientists, researchers and engineers came up with the idea of modern landfills which makes use of Leachate Collection System (LCS) to attenuate the toxicity of leachate emanating from landfills.

The main constraint to the performance of LCS is clogging of filter materials as a result of removal of organic and inorganic pollutants in leachate. Clogging of granular materials and liners decreases its hydraulic conductivity hence reducing the performance of the LCS. The components of LCS that affects its performance are particle sizes of granular materials used in LCS, presence of landfill liners, mass loading, and effect of using saturated and unsaturated gravels.

[6] Studied the effect of particle size distribution on LCS using columns packed with granular materials of different particle sizes ranging from 2 – 4, 4 – 8, 8 – 16, and 16 – 32mm respectively. At the end of studies, they concluded that fine grained particles were more susceptible to clogging than the coarse grained particles. This can be attributed to the reduction in hydraulic conductivity and drainable porosity of the fine grained particles because of its large surface area.

The effect of particle size distribution in LCS was also examined by [7]. Leachate was passed upward through columns containing glass beads with nominal diameters of 4, 6 and 15mm respectively. From their studies they concluded that the 4mm diameter glass beads experienced significant reduction in drainable porosity and hydraulic conductivity earlier than the 6mm and 15mm bead columns. This is because of the large surface area of the 4mm bead that allows more biofilm growth when compared with 6mm and 15mm beads. The increased reduction in Chemical Oxygen Demand (COD) of 4mm bead column signifies that it adsorbs more pollutant from the leachate when compared with 6mm and 15mm bead columns. Similar studies were carried out by [8], [9] and [10]. Their observations and conclusions followed the same trend.

The use of filter/liner in LCS is necessary because it helps in attenuating the pollutants present in the leachate. These filters reduce waste intrusion into the gravel hence, minimizing rate of clogging of the underlying saturated gravel. [11] Observed that presence of filter separators in LCS help to reduce the rate of clogging in the underlying gravel. This signifies that the concentration of pathogens, heavy metals and other pollutants found in leachate obtained as effluent from LCS with filter separators will be low when compared with LCS without filter separators.

Studies have shown that the filter-separators close to the inlet gets clogged easily because of high concentration of leachate pollutants available for these filter separators to adsorb. Hence, there is need to closely space the filter separators for optimum performance in other to reduce clogging. [12] Showed that clogging of glass beads in the experimental column was greatest near the inlet where leachate strength was greatest. Hence, they suggested that reducing the distance between the leachate collection pipes would decrease the total volume of leachate collected for one individual pipe, hence reducing mass loading and rate of clogging around the pipe.

Few literatures were found on the use of natural fibres as filters/liners to prevent leaching of toxic materials into groundwater. [13] Evaluated the effectiveness of juniper filter for removing phosphorous from watershed. They found out that juniper fibre has high affinity for phosphorous implying that it can be used as a liner in preventing seepage of pollutants into ground water. [14] Investigated the use of jute geotextile in adsorbing sulphate from landfills. Their studies showed that the use of jute geotextile as a landfill liner will minimize groundwater pollution. Their studies also revealed that jute geotextile treated with bitumen adsorbed more quantity of sulphate.

The aim of this research work is to determine the effect of jute fabric in attenuating nitrate concentration of the LCS, effect of different particle size of river sand on performance of LCS and effect of sampling nitrate concentration of the effluent from different points in the LCS.

II. METHODOLOGY

The river sand was sieved into three different particle sizes using sieve number 10 (1.67mm), sieve number 22 (0.699mm), sieve number 44 (0.35mm), sieve number 150 (0.104) and tray. The sand particles retained on sieve number 10 was discarded while sand particles retained on sieve number 22 was denoted as particle size P, the ones retained on sieve number 44 was denoted as particle size Q and the last particle size R was obtained by combining the sand particles retained on sieve number 150 and tray.

A known weight of the three different sand particle sizes was compacted into experimental columns having two sampling taps. For each particle size of sand, there were four different columns each column having 0-3 layers of jute fabric denoted as C, X, Y, and Z respectively. The columns without jute fabric served as the control. For control(s), equal weight of the sand was placed above and below the first tap while for the columns with one layer of jute fabric, the jute fabric was placed mid way of the sand. The columns with two layers of jute fabric was arranged by compacting one-third by weight of the sand into the columns followed by the jute fabric and then one-sixth by weight of sand above and below the first tap. Also, the columns with three layers of jute fabric was assembled by compacting one quarter of the sand, followed by the jute fabric and then one quarter of sand above and below the first sampling tap. The experimental set-up was saturated for two days.

The influent was introduced into the columns from the overhead tank at constant flow rate of 358cm^3/min. Nitrate concentration of the effluent was determined from top level, tap position one and tap position two concurrently using the sulfanilic acid method.

Standards were prepared. The absorbance readings were taken and the graph of absorbance against concentration plotted. The absorbance for the test samples were read off from the spectrophotometer. The concentrations of the test samples were derived from the graph of standard concentration against absorbance.

Table 1: Properties of Jute Fabric

Weight	Specific Gravity	Tensile Strength	Permeability	Type of Weave
700gm/m	1.3	300,000 KN/m^2	0.025cm/s	Woven

Table 2: Properties of River sand

	Particle size P	**Particle size Q**	**Particle size R**
Bulk density (kg)	1760	1646	1614
Porosity	0.916	0.905	0.899
Hydrodynamic dispersion(cm^2/min)	0.077	0.063	0.052
Pore water velocity(cm/min)	0.072194	0.068507	0.042449

III RESULTS AND DISCUSSION

A. Effect Of Using Different Particle Sizes

The three different particle sizes of river sand used in this study denoted by P, Q and R had particle sizes of 0.699mm-1.4mm, 0.35mm-0.5mm and 0.25mm-0.00mm respectively. Particle size R had the finest particles while P had the coarsest particles and Q is intermediate between R and P.

The concentrations of nitrate in the effluent obtained from each of the columns were different. Columns containing particle size R had the least concentration of nitrate in the early days while the concentration of nitrate in the effluent sampled from columns containing particle size P was higher when compared with nitrate content of the effluent tested from columns containing particle size Q. Contrasting results were obtained from the later days of the experiment. Nitrate concentration of the effluent decreased from columns containing particle size R to columns containing particle size P as shown in figure (1-2).

The difference in the adsorption capacities of the three different particle sizes could be attributed to the fact that particle size R has the largest surface area for adsorption followed by particle size Q and P. The large surface area of particle size R allows for more adsorption of nitrate in the early days of the experiment when compared with particle size Q and P. In the later days of the experiment, the large pore size of particle size P allows for even distribution of leachate through the experimental column and clogging is more uniform as shown in figure (1-2). Furthermore, the reduction in the drainable porosity and hydraulic conductivity decreases from particle size R, Q and P. This is why the clogging potential of the three different particle size of the river sand increases from particle size P, Q and R respectively.

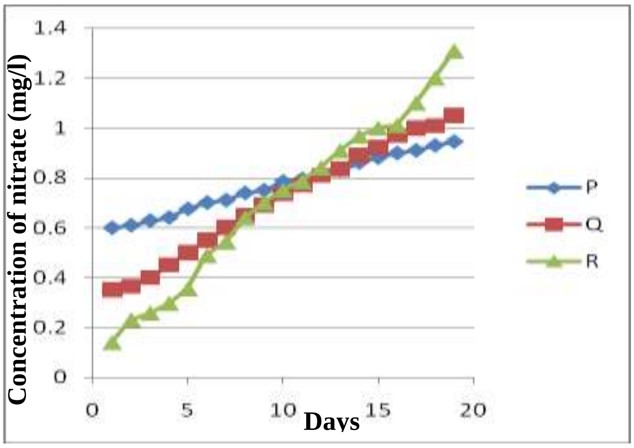

Figure I ***Variation of nitrate concentration with time using different particle sizes of river sand***

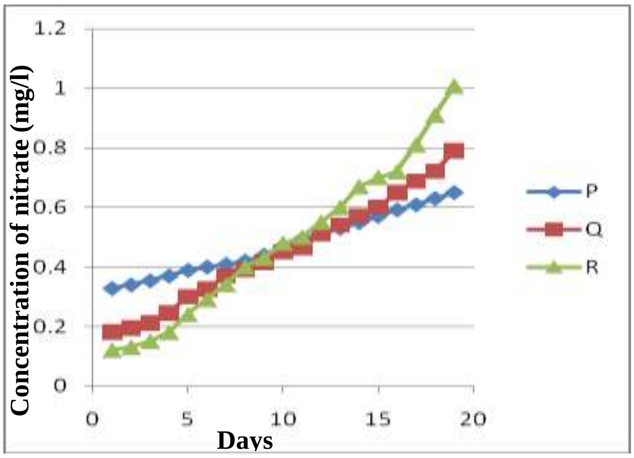

Figure II ***Variation of nitrate concentration with time using different particle sizes of river sand***

B ***Effect of Using Jute Fabric as Landfill Liner***

The performance of jute fabric as a landfill liner/ filter was investigated. Columns without jute fabric were denoted as C while columns with one layer, two layers and three layers of jute fabric were denoted as X, Y and Z respectively. From the experimental results obtained, concentration of nitrate in the effluent increased from columns with three layers of jute fabric to columns without jute fabric irrespective of the particle size as shown in the figure (3-5). This is because presence of the jute fabric increases the effective thickness of the column hence providing more surface area for adsorption of nitrate.

The use of jute fabric as landfill liner also prevents the physical intrusion of nitrate into the sand particles and subsequent reduction in void volume thereby reducing the clogging potential of LCS.

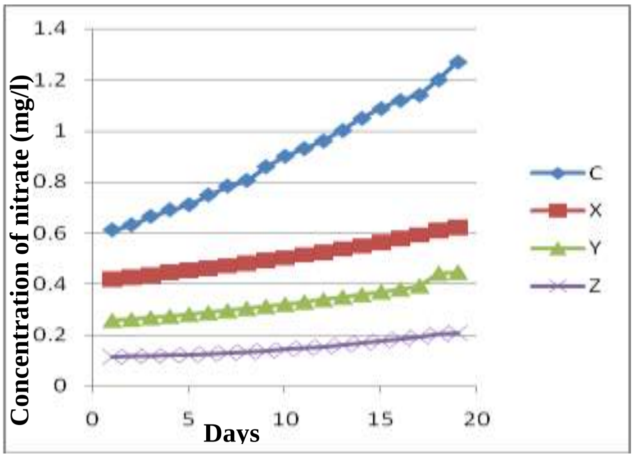

Figure III ***Variation of nitrate concentration with time using different number of jute layers for particle size P***

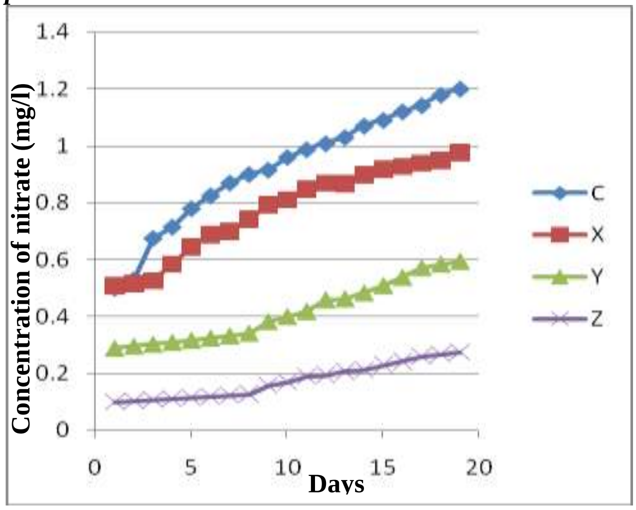

Figure IV ***Variation of nitrate concentration with time using different number of jute layers for particle size Q***

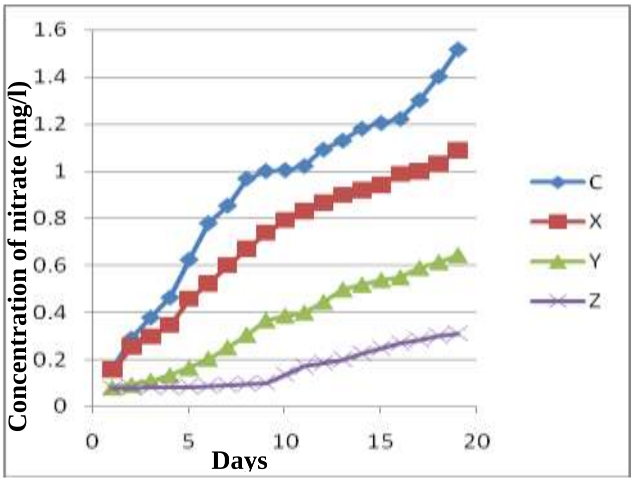

Figure V ***Variation of nitrate concentration with time using different number of jute layers for particle size R***

C *Effects of Sampling from Different Tap Locations*

Concentration of nitrate in the effluent was sampled from different points (i.e. the top level, tap position 1 and tap position 2). The laboratory results obtained indicated that the concentration of nitrate in the effluent decreased from top level to tap position 2 for the three different particle sizes of sand used as shown in (figure 6-8). This is as result of increased distance that the influent has to permeate before getting to tap position 2. The concentration of nitrate sampled from the top level was highest when compared with the other two sampling points because it is the closest to the inlet where the mass loading of influent is very high and hence it is easily clogged.

In addition, nitrate concentration of the effluent increases as one move from the bottom of the experimental column. This could be attributed to the decrease in effective depth of the column. Increase in the effective depth of the column increases pore space hence creating more surface area for nitrate adsorption

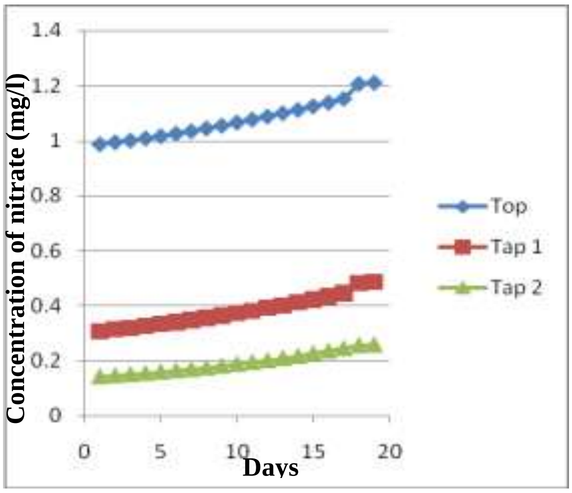

Figure VI ***Variation of nitrate concentration with time at different sampling locations in the column for particle size P***

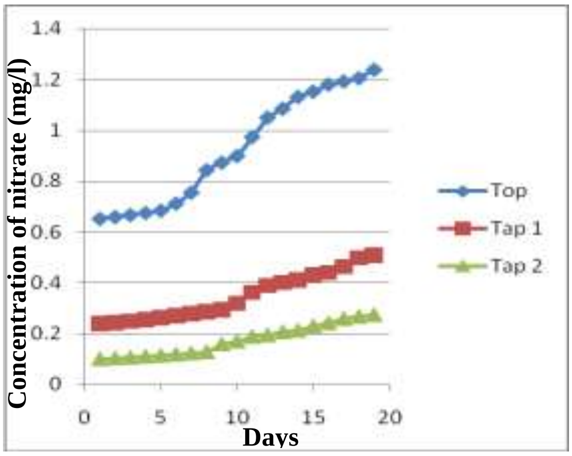

Figure VII ***Variation of nitrate concentration with time at different sampling locations in the column particle size Q.***

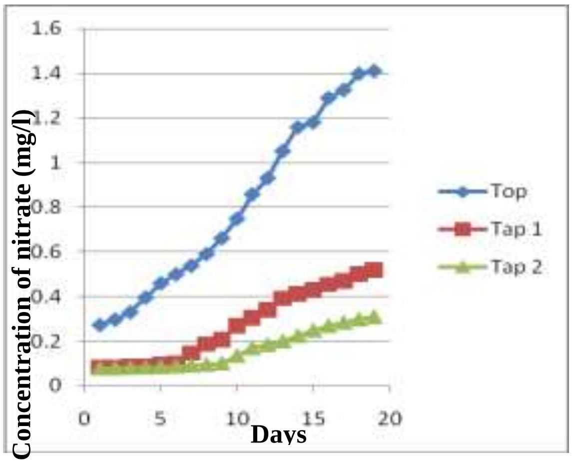

Figure VIII ***Variation of nitrate concentration with time at different sampling locations in the column for particle size***

IV. CONCLUSIONS

Jute fabric should be used as landfill liners since it is a good adsorbent. Performance of LCS can be improved by incorporating as many landfill liners as possible. This will provide more surface area for adsorption of landfill leachate pollutants. It will also reduce development of clog materials hence improving the life span of LCS.

River sand is a good adsorbent of nitrate. In order to increase the life span of Leachate Collection System (LCS), it should be designed with coarse particles of river sand. Coarse particles have large surface area for adsorption and hence clog development is at its minimum when compared with fine particles.

Furthermore, life span of LCS can be increased by increasing its effective distance. This will reduce the concentration of leachate pollutants contained in the influent. Also increasing the detention time will improve the performance of LCS.

REFERENCES

[1] Puckett L.J. “Identifying the major sources of nutrient water pollution”. Environmental Science and Technology, 29, 1, 408A-414A, 1995.

[2] Kross B.C; Hallberg G.R; Bruner D.A; Cherryhalmes K and Johnson J.K. “The nitrate contamination of private well water in Iowa”. American Journal of Public Health, 83, 270-27, 1993.

[3] Kadir A.A; Abdullah M.M.A.B; Sandu A.V; Noor N.M; Latif A.L.A and Hussin K. “Usage of palm shell activated carbon to treat landfill leachate”. International Journal of Conservation Science, 5(1), 117-126, 2014.

[4] Janerich D.T; Brunett WS; Feck G; Hoff M; Nasca P; Polednak A.P; Greenwald P and Vianna N. “Cancer incidence in the love canal area”. Sci, 212, 1404-1407, 1981.

[5] Heath C.W; Nadel M.R; Zack M.M; Chen A.T.L; Bender M.A and Preston J. “Cytogenetic findings in persons living near the Love Canal”. JAMA, 251, 1437-1440, 1984.

[6] Brune, M; Ramke H.G; Collins, H.J and Hanert, H.H. “Incrustation problems in landfill drainage systems”. Landfilling of waste: Barriers, E and FN Spon, London pp 415-421, 1994.

[7] Rowe R.K; Armstrong M.D and Cullimore D.R. “Particle size and clogging of granular media permeated with leachate”. Journal of Geotechnical and Geoenvironmental Engineering, 126, 775-78, 2006.

[8] Peeling, L; Pasky, A; Robinson J.P and Powrie W. “Removal of volatile acids from synthetic landfill leachate by anaerobic biofilms on drainage aggregates: A laboratory study”. Waste Management and Resource, London, 17, 141-149, 1999.

[9] Mclsaac R and Rowe R.K. “Change in leachate chemistry and porosity as leachate permeates through tire shreds and gravel”. Can. Geotech.J. 42, 1173-1188, 2005.

[10] Mclsaac R and Rowe R.K. “Clogging of gravel permeated with landfill leachate”. Journal of Geotechnical and Geoenvironmental Engineering, 133(8), 1026-1039, 2007.

[11] Mclsaac R and Rowe R.K. “Effect of filter-separators on clogging of leachate collection systems”. Can Geotech. J. 43, 674-693, 2006.

[12] Rowe R.K; Armstrong M.D and Cullimore D.R. “Mass loading and rate of clogging due to municipal solid waste leachate”. Canadian Geotechnical Journal, 37(2, 355-370), 2000.

[13] Han, J.S; Min S.H and Kim, Y. “Removal of phosphorous using AMD treated lingocellulosic material”. Forest Products Journal, 55(11), 48-53, 2005.

[14] Chattopadhyay B.C and Chakravarty S. “Containment of sulfate pollution in soil by natural geotextile from jute”. Journal of Materials in Civil Engineering,. 21 (3), 128-132, 2007.