

# SUBSURFACE CONTAMINATION IN THE VADOSE ZONE BY LEACHATE AT FOUR OPEN REFUSE DUMPS IN MAIDUGURI, NORTH EAST NIGERIA

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## ABSTRACT

The paper investigates the behaviour of four parameters namely chloride, sodium, potassium and nitrate underneath open dumps in an arid environment. Four sites were chosen for the study. These are University of Maiduguri (Unimaid), Lamisula, Wulari and the Kasuwa Shanu (Cattle Market) refuse dump sites. The first three are domestic solid waste dumps while the latter is an animal market waste dump. Soil samples were collected from these four dump sites. From each site was taken background sample at depths of 0.01m. All the parameters were detectable at all sites understudied at this depth. Chloride showed the clearest and most consistent behaviour at the four sites for the parameters tested. The consistency of chloride qualified it to be used as a base for consideration to establish any other consistent parameter. Chloride and/or sodium can be used as conservative tracers in the vadose zone of the arid region to monitor the movement of leachate to protect the ground water system. The natural soil studied exhibited attenuation properties.

**KEYWORDS:** solid waste, ground water, vadose zone, conservative tracer, attenuation.

## INTRODUCTION

Leachate is a liquid that results from water contaminants as it trickles through waste, agricultural pesticides or fertilizers, (Federal Environmental Protection Agency, 1991). There is health hazard associated with open dumping of refuse. These include menace of insects, rodents, foul odour apart from dotted and defaced urban aesthetic landscape (Ogunboye, 2003). Open dumps release various contaminants which lead to subsurface contamination (Ahel, Mikac, Cosovic and Proluc, 1999).

Groundwater has been exploited for domestic and other uses from earliest time (Genesis 26:18, The Holy Bible). The precise nature of its occurrence was not necessarily understood, but it has been successfully brought to the surface and groundwater use has been growing ever since (UNESCO-UNEP-WHO, 1992, 1996). Groundwater is particularly important in arid and semi-arid areas. There is a considerable degree of physico-chemical and chemical interdependence between the water and the containing material and the properties of both the ground and the water are important (UNESCO-UNEP-WHO, 1992, 1996). The unsaturated zone represents the first and most important natural defence against groundwater pollution (Lewis, Foster and Drasar, 1982; Foster, 1985; Matthess, Pekdeger and Schroter, 1985). This results from its position between the land surface and the water table. Additionally, a number of pollutant attenuation are more favoured by the environments of the soil and the

unsaturated zone. Water movement in the unsaturated zone is largely vertical and normally slow (UNESCO-UNEP-WHO, 1992, 1996). A previous work by Hojem (1988) showed that some lateral movement of contaminants in the subsurface occurs particularly when the depth of unsaturated soil below the landfill is large. The processes causing contaminant attenuation in the vadose zone include hydrodynamic dispersion, which causes dilution, and retardation; filtration, sorption and cation exchange causing retardation and elimination; precipitation, hydrolysis and complexation causing elimination. Other causes of elimination include biochemical transformation and volatilization (Foster and Hirata, 1988; Gowler, 1983). The effectiveness and magnitude of treatment offered by these or other natural mechanisms depend on the geological and hydrological conditions at a specific site (Wangen and Jones, 1984). Natural soils have varying capacities for reducing migration rates of different chemical species through them (Fuller, 1978; Cartwright, Griffin and Gilkeson, 1977). Robinson, Carey, Watson and Gronov, (1999) monitored the Stangate East landfill in Kent, the United Kingdom and stressed that the use of attenuation processes can effectively protect the water environment. The results showed that degradation within the unsaturated zone was a significant mechanism in reducing concentration of organic contaminants. Retardation also was important in retarding the movement of ammoniacal and potassium ions through the unsaturated zone. The metal concentrations (iron and manganese) subsequently decreased as a result of changes in pH values.

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Dumping on land is one of the most widely used methods of the final disposal of solid wastes (Mavropoulos and Kallampakos, 1999; Stegmann, 1995) and in Nigeria are mostly, open dumps without liners and/or leachate collection systems. This creates the possibility of leakage of various contaminants from such dumps which can lead to severe ground water contamination (Christensen, 1992; Kendorff, 1995).

Related work on six unlined landfill sites in South Africa focused on subsurface contamination by leachate (Fourie, Blight and Pinheiro, 1999). The results showed that significant attenuation of contamination is possible in the unsaturated soil and if the rate of movement is slow, attenuation processes have a long time in which contaminants may be treated naturally. The paper investigates the behaviour of four parameters namely chlorine, sodium, potassium and nitrate underneath open dumps in an arid environment.

### DESCRIPTION OF STUDY AREA.

Maiduguri is the capital of Borno State in North East, Nigeria. It is located between longitude  $13^{\circ} 14' E$  and  $13^{\circ} 16' E$ ; and latitude  $11^{\circ} 46' N$  and  $11^{\circ} 54' N$  of the equator and occupies an approximate area of  $200\text{km}^2$  within the semi arid region of the Sudan Savannah. Maiduguri has a high temperature in the hot dry season which occurs between the months of February and May and an average rainfall of 691mm (Nwaka, 1991).

### MATERIALS AND METHODS

Four sites were chosen for the study. These are University of Maiduguri (Unimaid), Lamisula, Wulari and the Kasuwa Shanu (Cattle Market) refuse dump sites. The first three are domestic solid waste dumps while the latter is an animal market waste dump. Soil samples were collected from these four dump sites.

The first soil samples at the four sites were collected at 0.01m depth after clearing away some of the refuse. Subsequent samples were collected at 0.2m intervals up to 1.2m, then at 1.5m and 2.0m. At this depth, the shovel could not be used for further digging and the auger (4m in length, fabricated at the University of Maiduguri workshop), and used to collect samples at 3m and 4m depths. The samples were put into

polythene bags and transported to the laboratory and stored at room temperature.

The soil was air-dried for 24 hours. Large lumps in each sample were broken and shaken through a sieve. The fraction passing was used for determination of contaminants. Prior to testing for potassium, sodium, chloride, and nitrate an extraction process was carried out. This consisted of mechanical agitation of the soil (in distilled water) for 2–2.5 hours, followed by filtration of the suspension. The filtrate was used for the analysis. Sodium and potassium were obtained using flame photometer.

## RESULTS AND DISCUSSION

### Background Values

From each site was taken background sample at depths of 0.01m. All the parameters were detectable at all sites understudied at this depth. The University of Maiduguri dumpsite had respective values for sodium, potassium, chloride and nitrate of 29.7, 113, 1.7 and 6.3mg/l. The Kasuwa Shanu dump results showed higher values than the Unimaid dump site. The values were 63.6, 162.5, 2.7 and 15.4mg/l for sodium, potassium, chloride and nitrate respectively. Detectable results were also measured at the Lamisula and Wulari dumpsites.

### Concentration Profiles

Contaminant concentration profiles have been used to illustrate the nature and extent of pollution that has occurred at the various dump sites understudied. These are shown in Figures 1 – 4. Below the background depth, all the parameters were detectable down to the 4m depth. At the Lamisula dump (Figure 1), potassium had a background value of 157.5mg/l. There was a progressive reduction in the profile concentration up to a depth of 0.4 with a value of 120.5mg/l at a depth 1.0m, the concentration of potassium under the Lamisula dump site increased to 125.5 mg/l from 120.5mg/l at 0.4m. Another increment occurred at depth 1.0m increasing the concentration to 118mg/l. Thereafter there was progressive reduction in concentration values giving a concentration of 24mg/l at 4.0m depth.

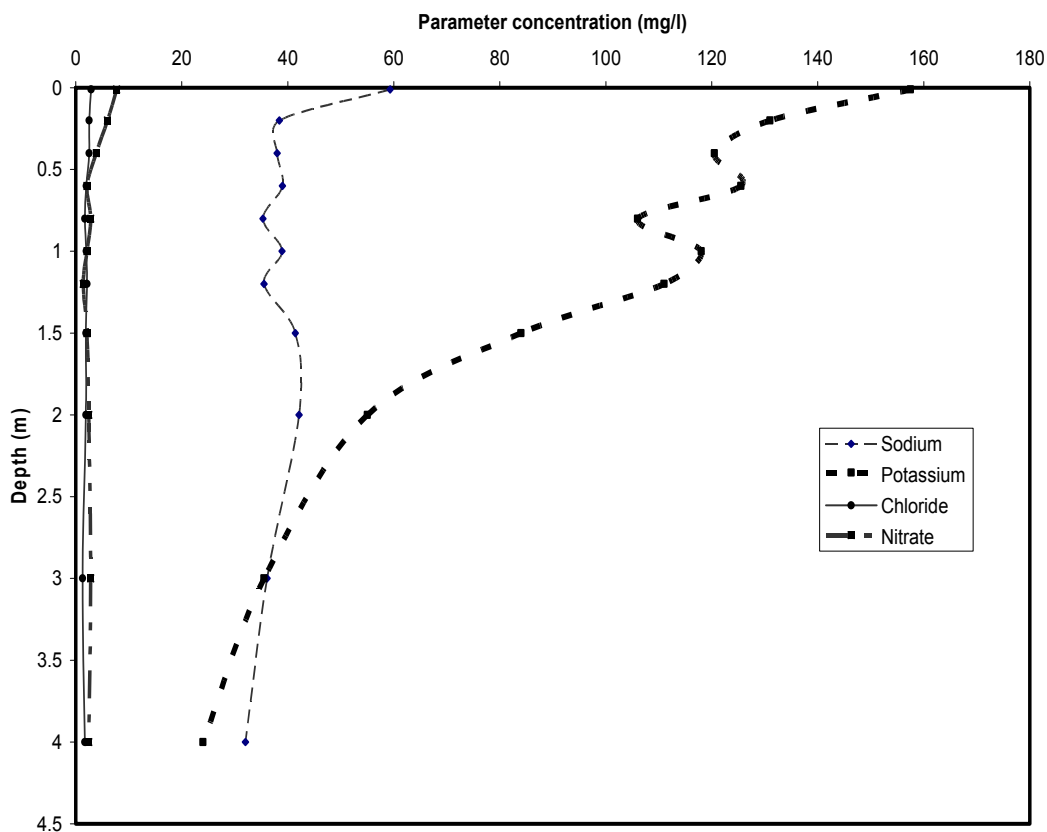


Fig 1 Concentration profile of parameters under the Lamisula refuse dump

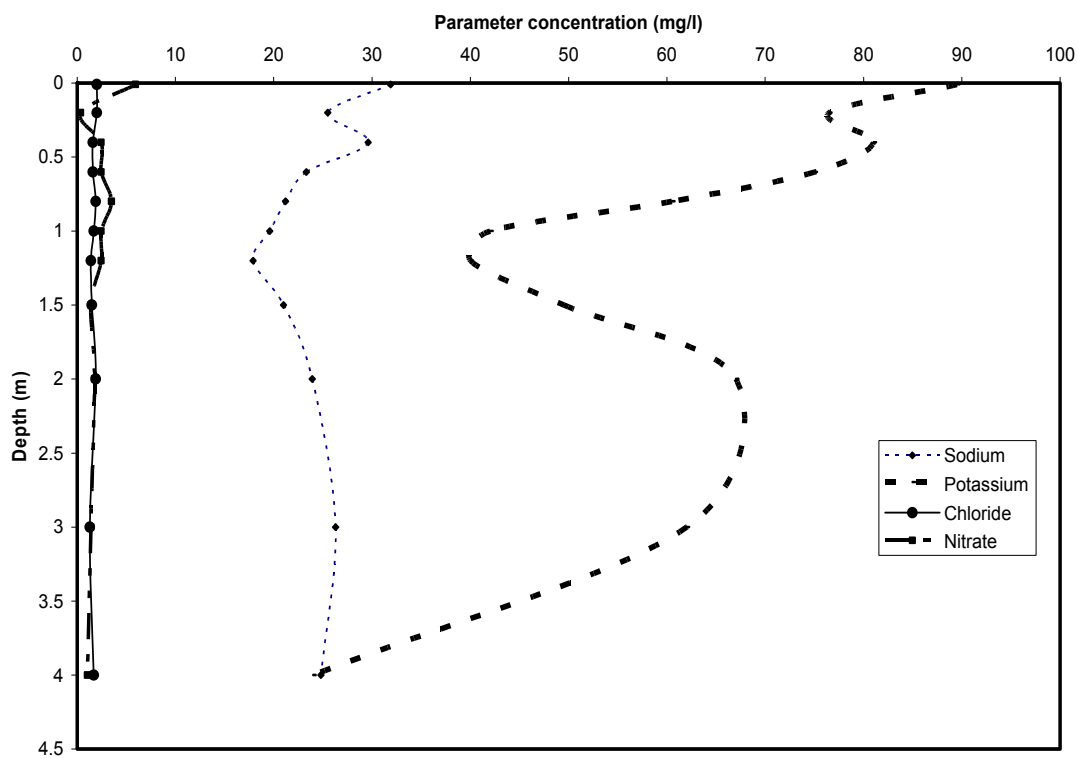


Fig 2 Concentration profile of parameters under the Wulari refuse dump

The Wulari dump site concentration profile for sodium, potassium, chloride and nitrate are also shown (Figure 2). A reduction in the concentration profile of potassium occurred at the Wulari dump site upto a depth of 1.2m (40mg/l) from a background value of 89.5mg/l. At depth 0.8m, the nitrate concentration markedly increased from 2.1mg/l to 4.2mg/l.

The University of Maiduguri dump site had a background sodium concentration value of 29.7mg/l (Figure 3). At the Unimaid dump site at depth 3.0m an increase in concentration of potassium occurred from 18mg/l to 22.5mg/l. Nitrate had an increment in concentration occurring at depth 1.2m (concentration of 6.65mg/l) from a concentration of 1.4mg/l at the 1.0m depth.

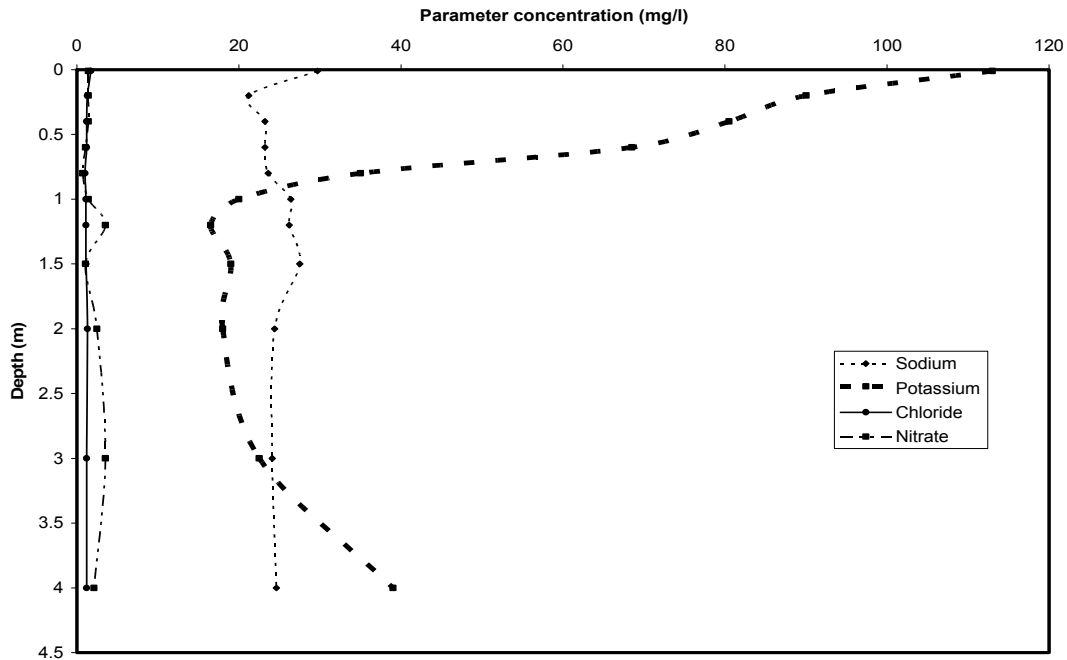


Fig 3 Concentration profile of parameters under the University of Maiduguri refuse dump

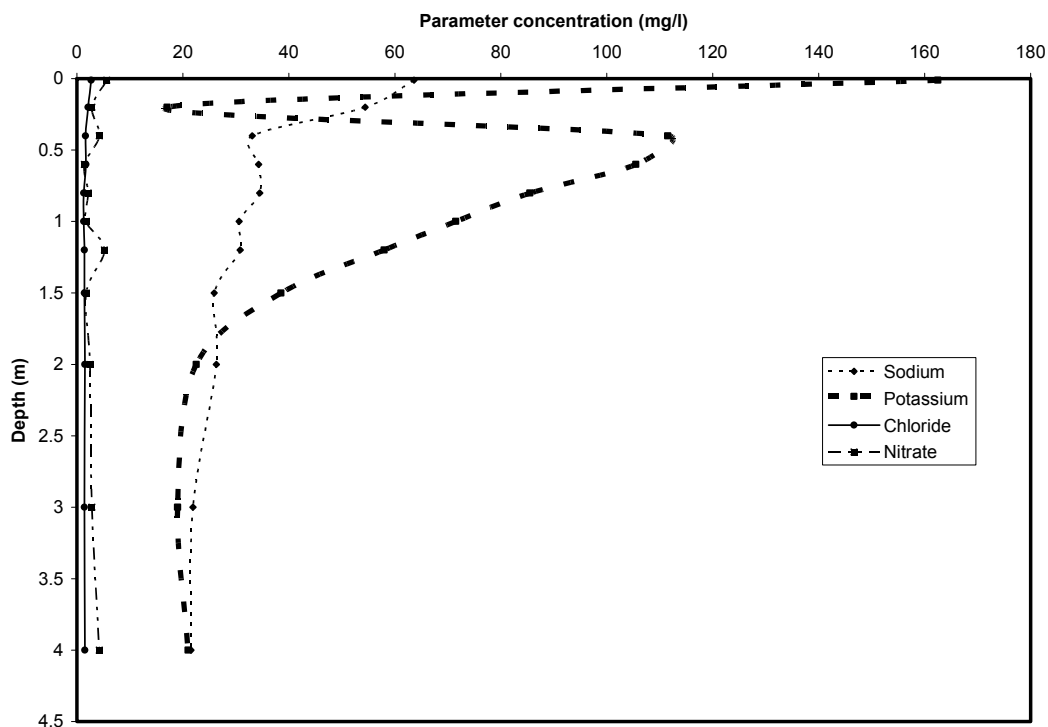


Fig 4 Concentration profile of parameters under the Kasuwan shanu refuse dump

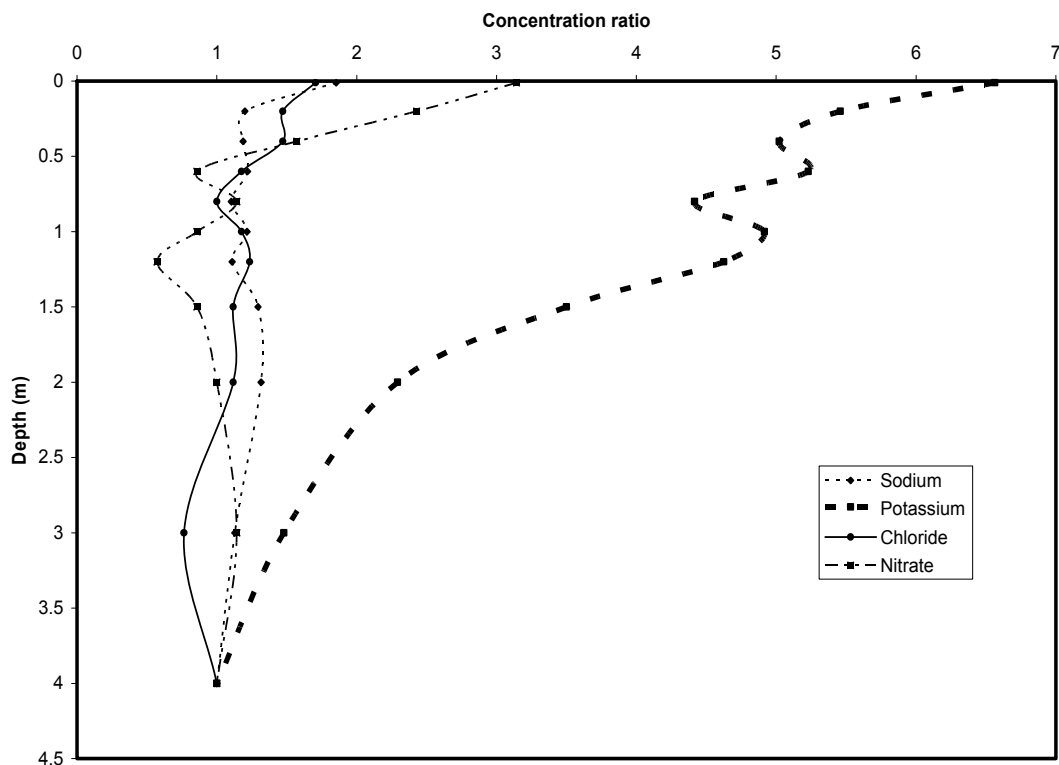
**Table 1:** Mean and Standard Deviation of Parameters

Location	Parameters			
	Sodium (Na)	Potassium (K)	Chloride (Cl)	Nitrate (NO <sub>3</sub> )
Lamisula	39.64 ± 6.79	97.09 ± 40.39	2.05 ± 0.43	3.25 ± 1.82
Wulari	24.09 ± 4.00	60.64 ± 19.04	1.69 ± 0.23	2.29 ± 1.42
University of Maiduguri	24.92 ± 2.25	47.46 ± 32.86	1.22 ± 0.18	1.81 ± 0.92
Kasuwan Shanu	34.26 ± 12.59	64.77 ± 45.41	1.63 ± 0.40	3.11 ± 1.38

At the Kasuwan Shanu refuse dump (Figure 4) sodium had a background value of 63.6mg/l. At 4m depth, the sodium concentration was 21.5mg/l, potassium with a background value of 162.5mg/l had a surge in concentration only at depth of 0.2m. Chloride shows the clearest and most consistent behaviour at all the four sites of all the parameters tested as shown in Table 1 with standard deviation ranging between 0.18 – 0.43. This is the least range in comparison to all the other parameters studied. This is to be expected as chloride has a conservative behaviour and except by dilution is not affected by attenuation (Robinson and others, 1999). The existence of nitrate at the levels tested is a good indication that some contamination is present at the sites studied. Sudden increments in nitrate concentrations in all the dumps may indicate the movement of a contaminant slug (Fourie and others, 1999).

used as a basis for consideration to establish any other consistent parameter. Consistent parameters are useful as conservative tracers. This comparison was achieved by plotting concentration ratios against depth in meters. The concentration ratios were obtained by dividing all other concentration values by the values at the 4.0m depth for all parameters. These are shown in Figures 5 to 8. The figures show sodium exhibiting properties very similar to chloride at all the sites. This qualifies sodium as a conservative tracer for use in the arid zone. At the Lamisula and Kasuwa Shanu refuse dumps, nitrate shows some similar behaviour to chloride unlike the University of Maiduguri and Wulari dumps. The nitrate concentrations reveal appreciable changes with profile; although Lewis and others (1980) and Fourie and others (1999) suggested nitrate as a conservative tracer in the unsaturated zone, this does not apply in the arid region studied.

The consistency of chloride qualified it to be



**Fig 5** Concentration ratio profile of parameters under the Lamisula refuse dump

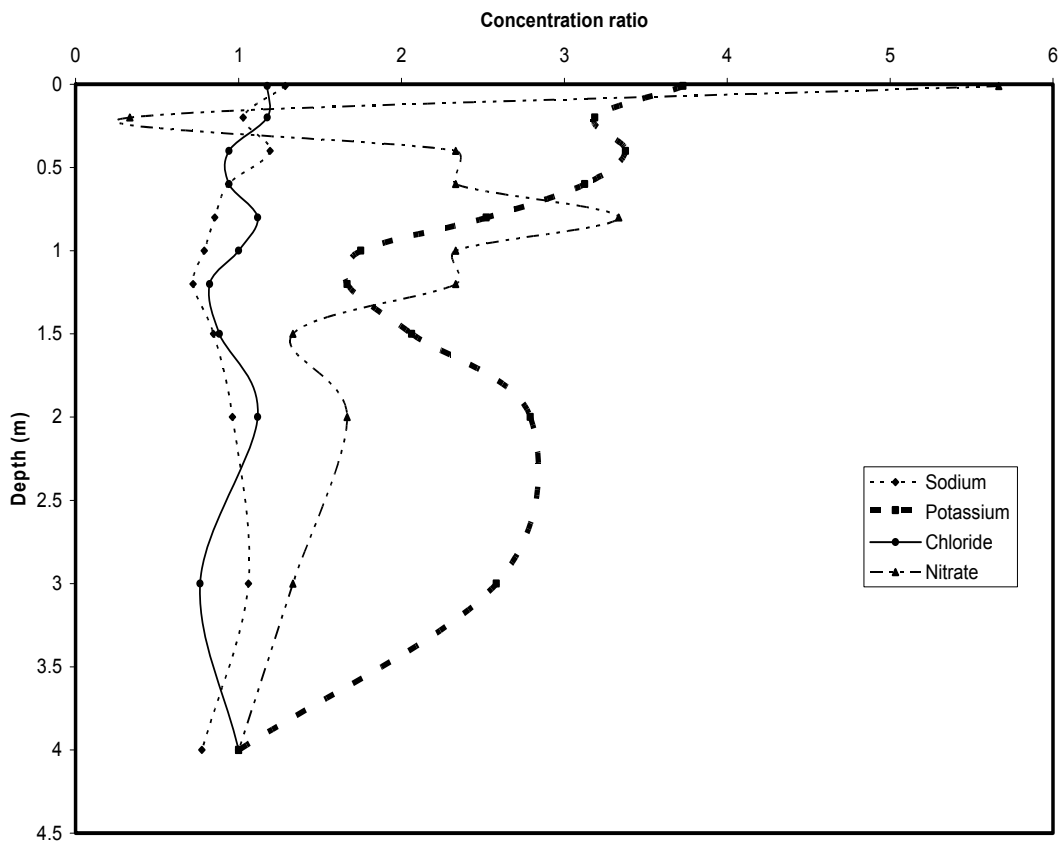


Fig 6 Concentration ratio profile of parameters under the Wulari refuse dump

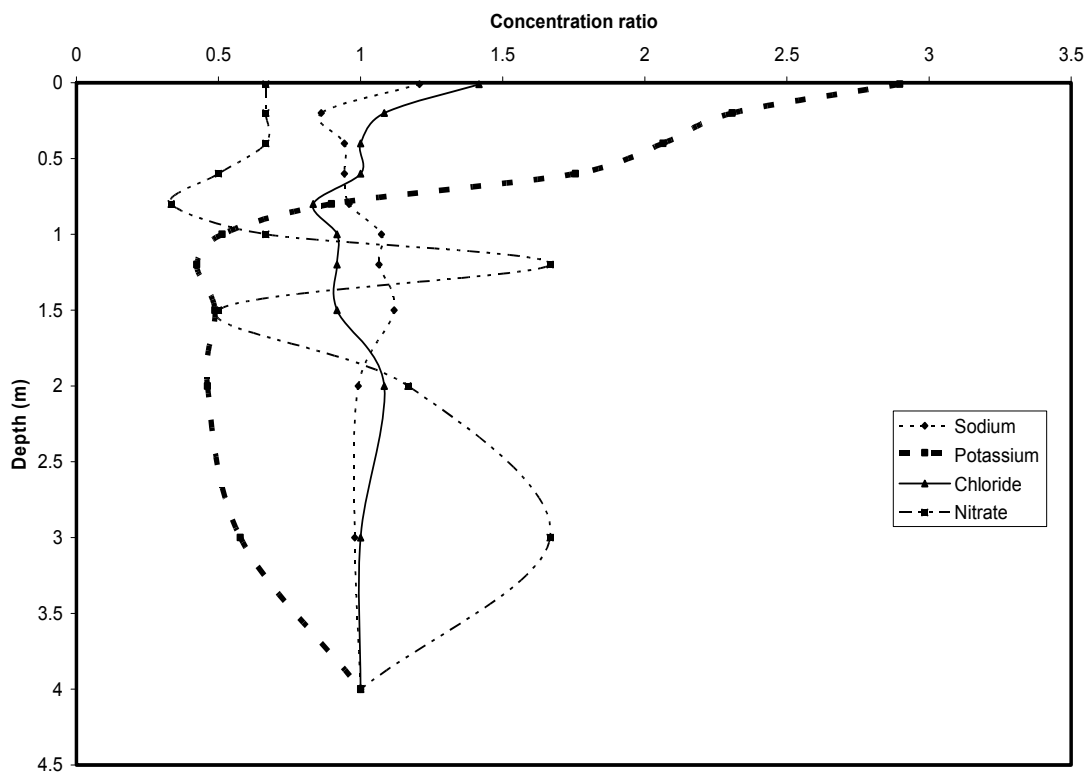


Fig 7 Concentration ratio profile of parameters under the University of Maiduguri refuse dump

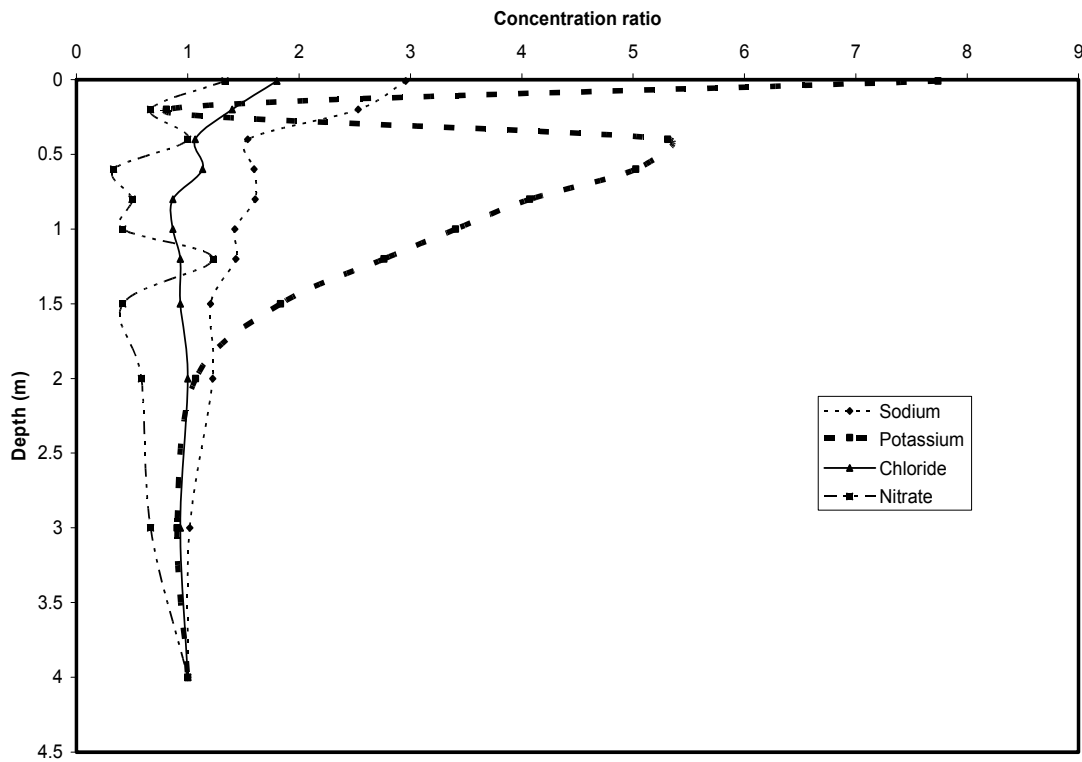


Fig 8 Concentration ratio profile of parameters under the Kasuwan Shanu refuse dump

**Attenuation properties**

Figure 9 shows the maximum attenuation for each parameter at the respective dumps. The results show that significant attenuation is possible in the unsaturated zone in Maiduguri. Nitrate was considered a conservative tracer by Fourie and others (1999) and Lewis and others. (1980). The

present investigation does not present nitrate to have such a characteristic in the vadose zone of the arid region investigated. In all the refuse dumps, nitrate was attenuated to above 79% of the background value. The results for sodium and chloride are consistent with the finding of Robinson and others (1999) as conservative in nature.

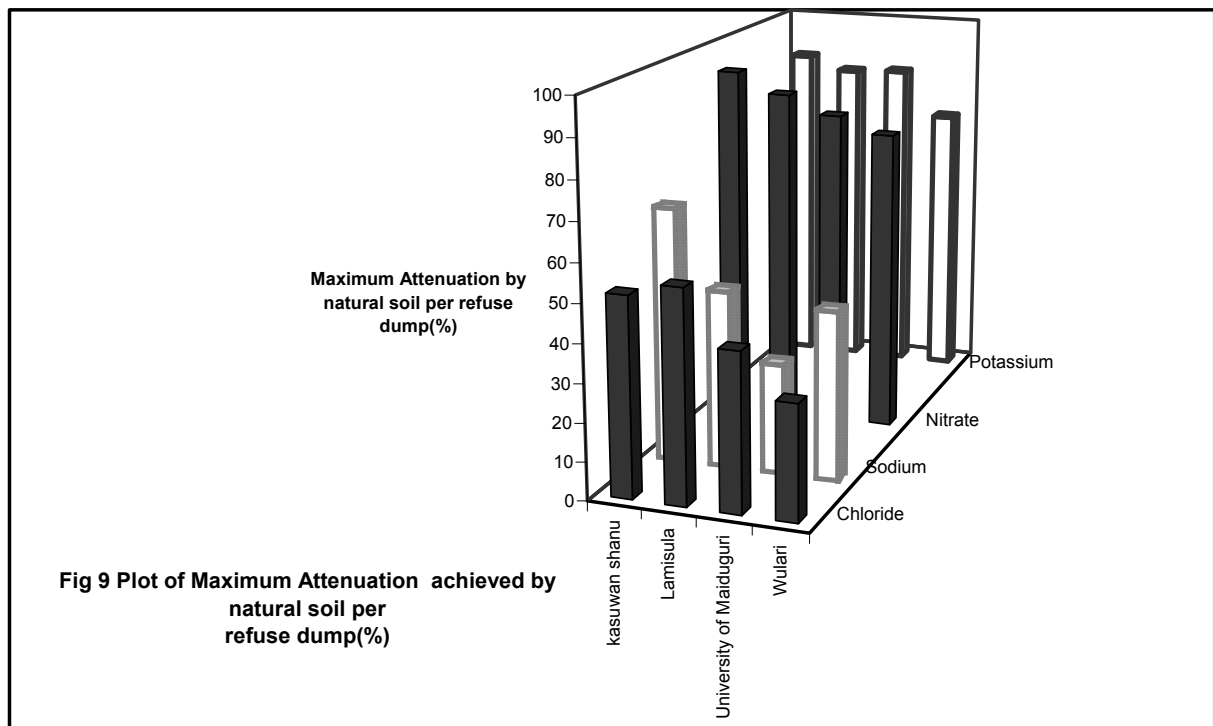


Fig 9 Plot of Maximum Attenuation achieved by natural soil per refuse dump(%)

## CONCLUSION

Soil samples obtained beneath four refuse dumps and at selected depth intervals up to a maximum depth of 4metres were examined for chemical composition. Two cations (sodium and potassium) and two anions(chloride and nitrate) concentrations were evaluated for soils at each refuse dump site. For each location, potassium and nitrate varied significantly with depth while there was minimal variations of chloride and sodium with depth. Chloride and sodium can be used as conservative tracers in the vadose zone of the arid region to monitor the movement of leachate to protect the ground water system . As potassium and nitrite can be attenuated by the unsaturated zone, natural soil columns can be used to treat potassium rich waste waters.

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