Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol 2, No.11, 2012 

# Analysis of Leachates from Solid Waste Dumpsites: A Tool for Predicting the Quality of Composts Derived from Landfills

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**Abstract**

Leachate and soil samples were collected near five solid waste dump sites in the Accra metropolitan area of Ghana over a period of six months. The leachate samples were analyzed for heavy metals, coliform bacteria and helminth eggs while the soil samples were analysed for only helminth eggs. Heavy metals analysed included Cd, Pb, Zn, Mn, and Cu. It has been observed that the leachates contain high levels of these heavy metals and pathogens. The high heavy metal levels make the solid wastes suitable for composting only after sorting since this would remove materials which serve as sources of these heavy metals. With the high faecal and total coliform levels, choice of composting temperature and period of intensive decomposition and curing, would be key in getting rid of the pathogens.

**Key words**: Solid waste dump sites, Landfills, Leachate, Heavy metals, Coliform bacteria, Helminth eggs, Compost quality.

## 1. Introduction

According to Baily, (1990) waste is unusable material arising from household, municipal and commercial facilities; industrial effluents and sludge. Waste management is also described as minimization, recovery, recycling, collection, treatment and disposal of these materials. In the industrialized world, waste management practices evolved in the 1970s focusing on reducing their environmental impacts (Tanskane, 2000). According to Read, (2003) this led to the creation of landfill sites, establishing waste transfer stations or redirecting waste collection routes (Truitt et al, 1999).

Waste collection forms a very fundamental yet a crucial aspect of waste management and presents peculiar problems as household waste is thrown out indiscriminately. The removal or collection frequency is determined mainly by the waste decomposition rate and the resulting offensive odour emission (Caincross and Feachem, 1993). In 1998 the volume of solid waste generated in Accra was estimated at 765,000 $m^3$ and that of liquid waste was 75,000 $m^3$ (EPA, 2002). According to EPA, (2002), the total volume of solid waste collection in the same year in Accra was 669,000 $m^3$, implying that around 96,000 $m^3$ of the waste was unaccounted for. Currently, it is estimated that the metropolis generates about 2,000 tons of solid waste per day (EPA, 2002). However, it is noted that only about 1,300 – 1,500 tons of the material is collected daily leaving the remainder unattended to. Caincross and Feachem, (1993) have indicated that in tropical cities, since waste may already start to decompose within one to two days, removal and collection is required in most cases on daily basis or at least on alternate days.

Several methods of waste disposal are available and landfills are the main means of waste disposal in the Accra metropolis. These landfills are large outdoor sites designed for waste disposal and are usually meant to avoid water related contamination with the immediate environment especially underground water as normally associated with open dumps. Leachate release is however an intergral part of landfills and is said to be water that gets badly contaminated by contacting wastes. It seeps to the bottom of a landfill and can be collected by a system of pipes. The bottom of the landfill is sloped with pipes laid along the bottom to capture the contaminated water and other fluid (leachate) as they accumulate (zerowasteamerica.org). It was noted that landfills ensure prompt burial of waste before it could be blown away, catch fire or attract vermin and also due to its capacity to accommodate a large amount of waste, it can be sited on an old mine strip, gravel or sand pits and quarries. Landfills are usually recommended as a feasible option for waste disposal considering the costs and environmental risks of open dumps. Landfilling was first introduced in Ghana in 2001 at Oblogo which has a base liner.

Municipal solid waste provides a lot of valuable materials which could be recycled into useful products. Components of municipal waste could be substituted for natural materials thereby helping to conserve both renewable and non-renewable resources (Edon-D-Enger and Bradley, 1995). Pickford, (1996) noted that there are many methods and technologies through which maximum benefits could be derived from waste utilization and composting is one such method.

Composting is the biological decomposition of biodegradable organic fraction of waste under controlled and aerated conditions to a state sufficiently stable for nuisance-free storage and handling and for safe use in land applications (Diaz et al, 1994). Municipal Solid Waste (MSW) compost processes include all the biodegradable component of the waste stream that decompose easily – paper, food waste, wood and yard trimmings. On the average these materials account for about 65% (by weight) of the MSW in the Accra metropolis (Fobil, 2002). The significant volume reduction associated with composting and the possible uses of compost makes MSW composting attractive as a potential means of diverting waste from the landfills.

Solid waste compost has the potential to be used in large quantities by the agricultural industry for crop cultivation. It can be used to increase the organic matter, tilt and fertility of agricultural soils (Dick and McCoy, 1993). It also has the ability to improve on aeration and drainage of heavy soil, enhance the water holding capacity and aggregation of sandy soils and increases soil cation exchange capacity. In addition, compost enhances soil porosity, improves resistance to erosion, improves storage and release of nutrients and strengthens disease suppression (USEPA, 1997).

The quality of compost derived from a given solid waste depends upon the composition of the waste material. Ghana has for some time now been considering composting as a method of waste utilization. It is therefore in place to consider the level of pollutants emanating from some of these waste materials which would serve as raw material source for composts. To achieve this, this work has looked at the heavy metals and coliform bacteria levels of leachates emanating from five landfill sites in the Accra Metropolis, and also looked at the helminth egg counts in soils derived from these waste dumps trying to ascertain how suitable wastes from the sites would be for use in compost preparation.

## MATERIALS AND METHODS

### Profile of the Study Area

Accra stretches between longitudes 5º 33` to 5º55`north and latitudes 0º15` to 0º 25` west along the Gulf of Guinea coast of the south-eastern part of Ghana. Generally, with an average of 20 m above sea level, the landscape is low-lying with few short irregular hills and depressions in some parts of the city. The built up area of the city extends beyond the boundaries of the Accra Metropolitan Assembly (AMA). The Accra metropolis is bordered by the Tema Municipality, Ga East, Ga West, and Ga South Districts which together form the Greater Accra Metropolitan Area (UN-HABITAT, 2009; Sam, 2009). Fig. 1a shows the map of the study area.

### Climate, Soils and Vegetation

Accra experiences a mean annual rainfall of about 730 mm while mean temperatures vary from 24 ºC in August to 27 ºC in March. The vegetation consists mainly of coastal-savanna grasslands, shrubs and some few mangroves in isolated areas. Market gardening is practised in few places particularly along major waterways where irrigation is possible to support all-year round farming. Vegetables like pepper, okra, cabbage, lettuce, onion and cereals like maize are the maim crops cultivated (AMA, 2006).

The geological formations consist mainly of the Precambrian Dahomeyan schist, granodiorites, granites gneiss and amphibolites and the Precambrian Togo series. The underground water table ranges between 4.80 metres to 70 metres. The main soil types include; Drift materials from wind-blown erosion, alluvial and marine mottled clays, residual clays and gravels from weathered quartzite, gneiss and schist rocks and lateritic sandy clay soils.

### Drainage Characteristics

The area has four major drainage Catchment systems, namely the Densu River Catchment and Sakumo Lagoon, is the largest river basin and covers about 2,500 $km^2$ including settlements like, Dansoman, Kwashieman, McCarthy Hill and Awoshie areas; the Korle-Chemu Catchment basin which covers an area of 250 $km^2$; the Odaw River which is the main stream in this system with the Nima, Onyasia, Dakobi and Ado as tributaries; the Kpeshie Catchment drainage basin which covers an area of 110 $km^2$ on the eastern part of Accra, Ridge, Cantonments, Osu, Labadi and Burma camp areas and the Songo-Mokwe Catchment which covers about 50 $km^2$, draining the area of Teshie to the ridgeline with the Sakumo II catchment.

### Sampling

For easy identification, the sampling sites were given codes as shown in Table 1. The samples for analysis were leachate and soil. Sampling for the determination of chemical and biological parameters was done over a six-month period beginning June, 2009 and ending November, 2009. The wet season samples were obtained in the months of June, July and August while the dry season samples were taken during the period of September, October and November. The locations of the sampling sites were established using a Garmin 45 Ground Positioning System (GPS) as shown in table1.

**Sample Collection and Analyses**

Leachate samples were collected into 1-litre plastic bottles, which had been adequately washed with detergents, rinsed several times with de-ionised water and conditioned. Two sets of samples were taken at each sampling site, making a total of sixty leachate samples. Soil collection was done with pre-cleaned Polyethylene Shovel (Chen, et al 1997). The shovel was used to scoop the soil from 10-15 cm depth with hand glove and put into pre-cleaned polyethylene bags. At each sampling site, the soils were sampled at different spots to the same depth and composited giving a total of thirty soil samples for the study.

**Laboratory Analysis**

The determination of heavy metals was done at the Ecological Laboratory of the University of Ghana while other biological parameters were determined at the Council for Scientific and Industrial Research, Water Research Institute (CSIR/WRI) laboratories in Accra. Biological parameters determined included total coliforms, faecal coliforms and helminth eggs.

**Heavy metals determination**

The acidified leachate samples (100 ml) after filtration with preconditioned plastic Millipore filter unit equipped with a 0.45μm filter (Gelman Institute Co, London) were digested with 1:10 mixture of concentrated $HNO_3$ and 30% $H_2O_2$ to concentrate and convert metals associated with particulate matter to the free metal ions. The solutions were then determined for Cd, Pb, Zn, Mn, and Cu levels using Perkin Elmer Analyst 400 Atomic Absorption Spectrophotometer (AAS).

**Determination of Biological Characteristics**

Biological characteristics determined were, faecal and total coliforms and helminth eggs. This was done using the Membrane Filtration (MF) technique which used an enriched lactose medium and incubation temperature of $44.5^oC \pm 0.2^oC$ and this gives 93% accuracy in differentiating between coliforms found in the faeces of warm-blooded animals and those from other environmental sources (Spellman and Drinan, 2000). One litre of leachate and 20 g (wet weight) of soil samples were used for the analysis of helminth egg count. All species of helminth eggs in the samples were quantified using the concentration method (Schwartzbrod, 2000). The identities of the specific helminth eggs were established using the WHO bench aid for the diagnosis of intestinal parasites (WHO, 2006).

**RESULTS AND DISCUSSIONS**

**CHEMICAL PARAMETERS OF LEACHATE SAMPLES**

**Heavy Metals in Leachate Samples**

Leachate samples were treated and analysed for Cd, Pb, Zn, Mn, and Cu. Figure 1b shows pictures of leachate emanating from one of the landfill sites that was used for the study.

**Cadmium (Cd)**

Cadmium is a non-essential metal that is toxic even when present in very low concentrations. The toxic effect of the metal is exacerbated by the fact that it has an extremely long biological half-life and is therefore retained for long periods of time in organisms after bioaccumulation (WHO, 1992). Figure 2 is a graphical representation of the mean seasonal cadmium content in leachate from the sampled sites. These values ranged from 0.0016 mg/l at Mallam New site to 0.0126 mg/l at Teshie-Nungua in the wet season and 0.0013 mg/l at Mallam Old Site to 0.0106 mg/l at Kwashiebu in the dry season. No defined seasonal trend has been observed for the metal as can be seen from fig. 2.

The presence of cadmium could be due to the discharge of municipal solid waste (MSW) at the landfill/dumpsites which contain nickel-cadmium batteries, discarded consumer electronic products such as televisions, calculators, stereos and plastics (Woodbury, 1992). The content of cadmium in the leachate samples were lower than the British Environment Agency guideline value of 1.8 mg/kg (http://www.enviroment-agency.go.uk) for soils. However, continuous leaching may increase its level which would pose a danger for the use of the waste for composting as cadmium is known to affect the growth of plants in experimental studies, although no field effects have been reported (AMAP). Stomatal opening, transpiration and photosynthesis have been reported to be affected by cadmium in nutrient solution. As metals are taken up into plants more readily from nutrient solution than from the soil, terrestrial plants may accumulate cadmium in the roots and the metal is also found bound to cell walls (AMAP, 1998).

**Lead (Pb)**

The levels of the metal ranged from 0.104 mg/l at Oblogo to 0.629 mg/l at Teshie-Nungua in the wet season. The dry season values also ranged from 0.027 mg/l at Oblogo to 0.483 mg/l at Teshie-Nungua. There was a clearly defined seasonal trend, as the wet season values were higher than those of the dry season, fig. 3.

The presence of lead in the leachate may be from lead-acid batteries, plastics and rubber remnants, lead foils such as bottle closures, used motor oils and discarded electronic gadgets including televisions, electronic calculators and stereos (Woodbury, 1992) at the landfill sites. Due to its high toxicity, lead levels in soils are usually expected to be very low. The New Zealand Ministry for Environment guideline value of the metal in soil is 0.015 mg/kg (http://www.mfe.govt.nz). The mean values of the metal in the leachates have however been found to be above this level and composting waste from the landfills are likely to contain high levels of the metal which would subsequently impact plants especially vegetables. As a result of the high levels of the metal in leachate from the Teshie-Nungua site in particular, unsegregated MSW used for composting at this site would contain very high levels of lead.

Decreased growth and yield have been observed in plants grown in Pb contaminated soils. Balba et al, (1991) observed a significant decrease in plant biomass yield with increasing Pb treatment that varied with soil type. The highest adverse effects were on those plants grown in soils with high clay content. Khan and Frankland, (1983) also observed decreased plant growth and yield in soils with Pb contamination.

**Copper (Cu)**

Recorded mean values of copper ranged from a minimum of 0.025 mg/l at Oblogo to 1.018 mg/l at Teshie-Nungua in the wet season and 0.006 mg/l at Oblogo to 0.338 mg/l at Teshie-Nungua in the dry season. The presence of copper in the leachate may be due to the discharge of industrial waste containing copper residue at the landfill. The metal may come from disposal of waste from petrochemicals and agro-based industries, which contain pesticides and fertilizer residues (Pierce et al, 1998).

There was a clearly defined trend in the seasonal variation with the wet season recording higher values than the dry season as illustrated in fig. 4 which is a graphical presentation of the seasonal mean concentrations of copper in the leachate samples. Availability of water during the wet season should be aiding the leaching of the metal from the solid waste during the wet season.

Heavy metals especially copper may be toxic to fish as well as harmful to human health. Since copper is highly toxic, the release of leachates containing copper may pose a lot of harm to the environment, both terrestrial and aquatic. The extremely high values of the metal obtained at Teshie-Nungua during the wet months are above the New Zealand Ministry for Environment guideline value of 0.02 mg/kg for soils (http://www.mfe.govt.nz) and could be a source of contamination if MSW is not source-segregated before compost preparation.

**Manganese (Mn)**

Fig. 5, graphically illustrates the mean values of manganese in leachate samples collected from the landfill sites. Mean values ranged from 0.161 mg/l at Oblogo to 0.900 mg/l at Teshie-Nungua in the wet season and 0.210 mg/l at Oblogo to 0.471 mg/l at Teshie-Nungua in the dry season. There was no clearly defined trend in seasonal values.

The presence of manganese in the sample may be due to the discharges at the municipal landfill site including sewage sludge, waste from petrochemical, steel and iron production industries. Manganese is also an essential element but a known mutagen (Woolhouse, 1983). The accumulation of Mn may cause hepatic encephalopathy. Moreover, the chronic injection of Mn in drinking water is associated with neurological damage (Kondakis et al, 1989). Soils for that matter composts, containing high levels of the metal should be of concern since plants can be impacted.

**Zinc (Zn)**

The mean seasonal values of zinc concentrations in the leachate samples from the various sampled locations are graphically illustrated in fig. 6. These mean seasonal values ranged from 0.143 mg/l at Oblogo to 3.449 mg/l at

 

Teshie-Nungua in the wet season and 0.172 mg/l at Oblogo to 0.947 mg/l at Mallam New site in the dry season. The presence of Zn in the leachate might have come from incineration ash disposed off at the landfill sites. It may also be due to Zinc residue contained in waste after electroplating, smelting and ore processing (ATSDR, 1994) disposed off at the municipal landfill sites.

The most common health effects of high oral exposure (that is >85 mg/kg/day) to zinc are anaemia (and copper anaemia), caused by zinc displacing iron and copper in the blood and decreased HDL cholesterol which can lead to cardiac disease. The Canadian soil quality guideline for the metal is 200 mg/kg (http://ceqg-rcqe.ccme.ca). Despite the relatively low recorded values in the leachate, waste from especially the Teshie –Nungua site may pose a problem given the values recorded for the site. Compost from this site is likely to contain unacceptable levels of the metal for soils.

When the mean seasonal levels of the five metals were subjected to analysis of variance at 5% confidence interval, significant differences were observed in both spatial ($p<0.005$) and temporal ($p<0.05$) variations for all the sites. A Post Hoc Test of ANOVA also revealed that levels of all the metals from Teshie-Nungua differed significantly from the rest of the sites. Levels of the metals at Kwashiebu also differed significantly from those of Mallam Old site, Mallam New site and Oblogo except for Cu where recorded levels at Kwashiebu showed no significant differences from Mallam Old site, Mallam New site and Oblogo.

**Bacteriological Parameters.**

**Total Coliform (TC)**

Fig. 7, graphically illustrates the mean seasonal total coliform population in the leachate samples for the sampling sites. Total coliform counts in the leachate ranged from $64.0\times10^4$ cfu/100ml at Oblogo to $224.0\times10^4$ cfu/100ml at Kwashiebu in the dry season. The wet season values recorded ranged from $125.3\times10^4$ cfu/100ml at Teshie-Nungua to $474.0\times10^4$ cfu/100ml at Oblogo. The TC values recorded were extremely high and there was no clearly defined seasonal trend.

The dumping of human waste, agricultural waste (including plants and animal origins), sewage sludge and indiscriminate defaecation might have accounted for the significantly high levels of total coliforms in the leachates. Consequently, there is a high risk of pathogenic infections if these sources of waste are used for composting without the appropriate treatment. According to USEPA, (1997), disease risks associated with the pathogens may result from pathogens that are normally in the raw waste (called primary pathogens) or from fungi and actinomycetes that grow during composting (called secondary pathogens).

The primary pathogens such as bacteria, viruses, protozoa and helminths can initiate an infection in healthy individuals while secondary pathogens usually infect people with debilitated immune system(USEPA, (1997).

**Faecal Coliforms (FC)**

Fig. 8, graphically illustrates the mean faecal coliform counts in leachate samples for the sampling sites. The mean values ranged from $5.2\times10^4$ cfu/100ml at Kwashiebu to $12.2\times10^4$ cfu/100ml at Mallam Old site in the wet season. The mean values for the dry season ranged from $11.1\times10^4$ cfu/100ml at Mallam New site to $112.1\times10^4$ cfu/100ml at Oblogo. There was a clearly defined trend in the seasonal variations as the dry season values were higher than the wet season ones. The FC values recorded in the leachate samples were very high. The elevated levels may be due to the disposal of domestic and human faecal material contained in the municipal waste at the landfill sites. It may also be attributed to sewage sludge disposal at the landfill sites (Chapman, 1996).

Mean seasonal total and faecal coliform populations for the sites were subjected to analysis of variance at 5% confidence interval and results showed significant differences in both spatial and temporal variations. A Post Hoc Test of ANOVA revealed that coliform levels at Oblogo were significantly higher than the other sites.

The range of faecal coliform for which there is no risk of microbial infection from domestic and farm use is zero. Values of >20 cfu/100ml indicate significant and increasing risk of infectious disease transmission. All the sites fell far in excess of this range. Especially, compost from the Teshie-Nungua site could be a major source of microbial infection to humans, animals and plants.

**Helminth**

Mean seasonal helminth ova were found to be higher in soils than the leachates. The highest mean value of 0.83 per 500 ml volume of leachate was recorded at Mallam Old site while the highest for the soil was 9.99 per 10 g dry weight of the soil and recorded at the same site. Fig. 9 shows a graphical representation of the levels where generally the soils show higher levels than the leachate.

 

Mean seasonal helminth levels when subjected to analysis of variance at 5% confidence interval also showed significant differences in both spatial and temporal variations. A Post Hoc Test of ANOVA however revealed that the level recorded at Mallam Old site was significantly higher than the other sites except Kwashiebu.

Helminths usually cause tissue damage, toxic effects and blood loss to humans (Theis et al, 1978). Infestation with *A. lumbricoides, a type of helminth* is known to cause intestinal complications and massive gastro-intestinal bleeding. The prevalence of soil transmitted helminthic infection has also been reported by other workers (Atukorala and Lanerolle, 1999). Philippe, (1997) and Traub, et al, (2002) reported that by gardening or walking bare-foot outside, humans are potentially exposed to soils contaminated with helminth.

**5. Conclusion**

Compared to the total amount of heavy metals disposed off into landfills, the content of heavy metals in leachates is usually relatively low. Major part of the metal is retained in the landfill and as a consequence, it must be expected that leaching of heavy metals from landfills will continue for a long time (EEA, 2000). Since almost all the landfills in Ghana are not engineered, except a current one that is being constructed at Adzen Kotoku in the Greater Accra region at the cost of $25million (http://theheraldghana.com) the collection of leachate for treatment is non-existent.

Generally, the poor state of waste management is clearly not only an engineering problem. Rapid urbanization, poor financing capacity of local authorities, low technical capacity for planning and management of solid waste, weak enforcement of environmental regulations which allow local authorities to flout environmental regulations without any sanctions have all contributed to compound the problem. Current waste management practices are unable to keep pace with the waste generation rate. The failure is the result of complete dependence on government subsidy and external funding both for the establishment and maintenance of waste management facilities with virtually no arrangement for internal revenue generation for operational maintenance purposes.

Invariably, all the landfills surveyed within the Accra metropolis are primarily open dumps without leachate and gas recovery systems. They are located in ecologically or hydrologically sensitive areas and are generally operated below the recommended standard of sanitary practice. Municipal budgetary allocations for operation and maintenance are inadequate. Thus many of the landfills/dumpsites pose a great risk to both the environment and to the health of humans they are supposed to safeguard.

The use of wastes from the landfills for composting presents a great challenge. The high levels of heavy metals detected pose a danger to plants since such metals are easily absorbed and can be found in edible parts of the plants especially vegetables. Leachate analysis would therefore provide a fair idea about the level of heavy metals expected in the composts derived from the landfill and help predict the quality of the compost. This information would therefore guide the extent of sorting, which should aim at removing the materials that serve as sources of these heavy metals and would lower the levels in the waste since heavy metals in leachates are usually relatively lower than the amount trapped in the waste.

The high content of faecal and total coliforms and helminth eggs expose workers on the composts to infestations by these pathogens. Prohibition of defecation by humans and stray animals on these landfills would largely lower the levels of these pathogens and make working on the composts relatively safe. It is a known fact that composting involves the aerobic decomposition of organic materials using controlled temperature, moisture and oxygen levels. The mixture is stored ( in windrows, static piles, or enclosed tanks) for a period for intensive decomposition during which temperatures can rise well above $55^oC$ and depending on ambient temperatures and process chosen, the time required to reduce pathogens and produce class B, biosolids can range from three to four weeks (USEPA, 1999). In view of this fact, the temperature to be maintained and the time required to reduce pathogens can be worked out depending on the levels of pathogens recorded from the leachate analysis and help predict the quality of the compost derived from the landfill materials.

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Table1: Landfill sampling sites, types of sample collected, geographical locations and site elevations.

| Sampling Site Codes | Sample Site Description | Type of Sample | Site Locations | Site Elevation (feet) |
|---|---|---|---|---|
| TN | Teshie-Nungua | Leachate | 05° 36.607′N; 00°06.999′W | 71 |
| | | Soil | 05° 36.740′N; 00°06.100′W | 81 |
| KB | Kwashiebu | Leachate | 05° 35.951′N; 00°16.169′W | 103 |
| | | Soil | 05° 35.894′N; 00°16.120′W | 143 |
| MN | Mallam (New Site) | Leachate | 05° 34.081′N; 00°17.996′W | 236 |
| | | Soil | 05° 34.057′N; 00°18.025′W | 198 |
| MO | Mallam (Old) | Leachate | 05° 34.386′N; 00°17.376′W | 28 |
| | | Soil | 05° 34.386′N; 00°17.376′W | 31 |
| OB | Oblogo | Leachate | 05° 33.653′N; 00°18.653′W | 3 |
| | | Soil | 05° 33.801′N; 00°18.730′W | 121 |

Source: Field Survey, 2009

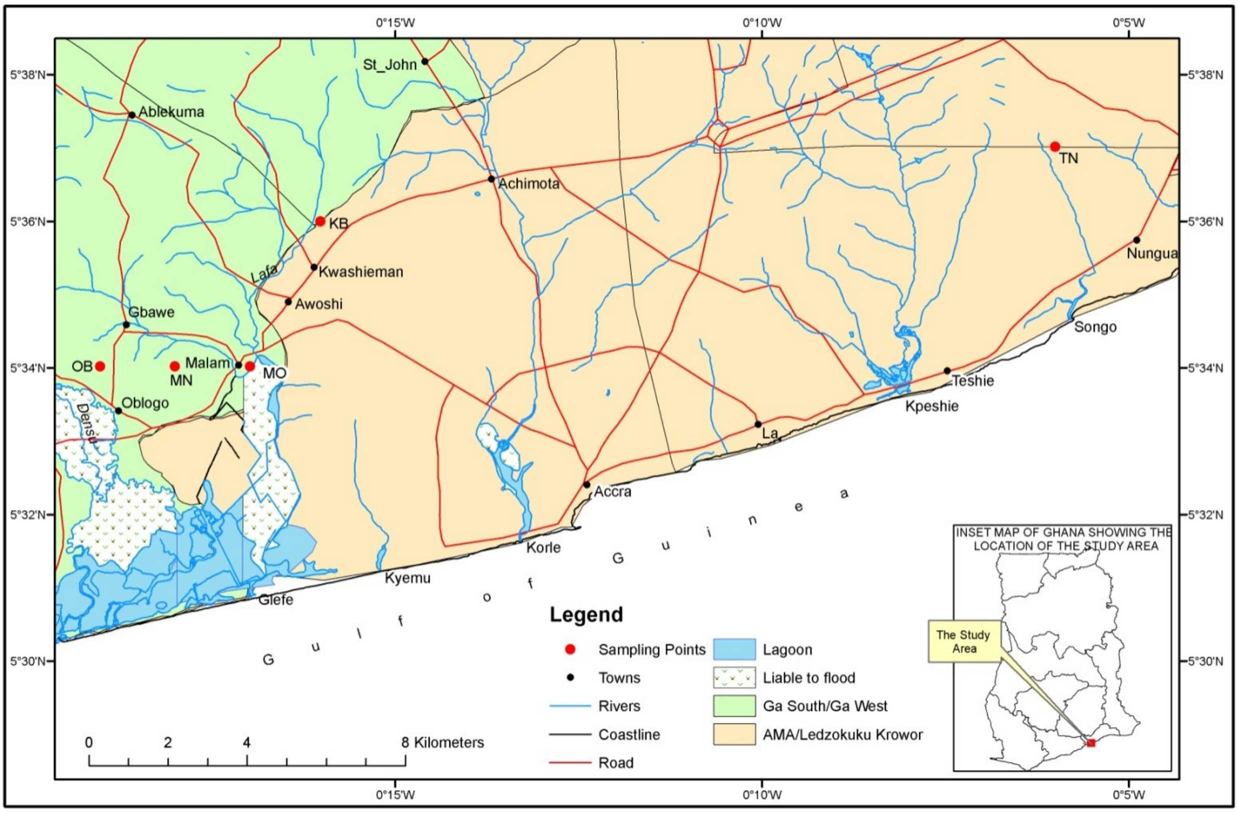


Fig. 1a : Map of the study area showing the sampling points

Fig. 1b: Leachate Emanating from the Oblogo Landfill Site (Source: Field Survey, 2009)

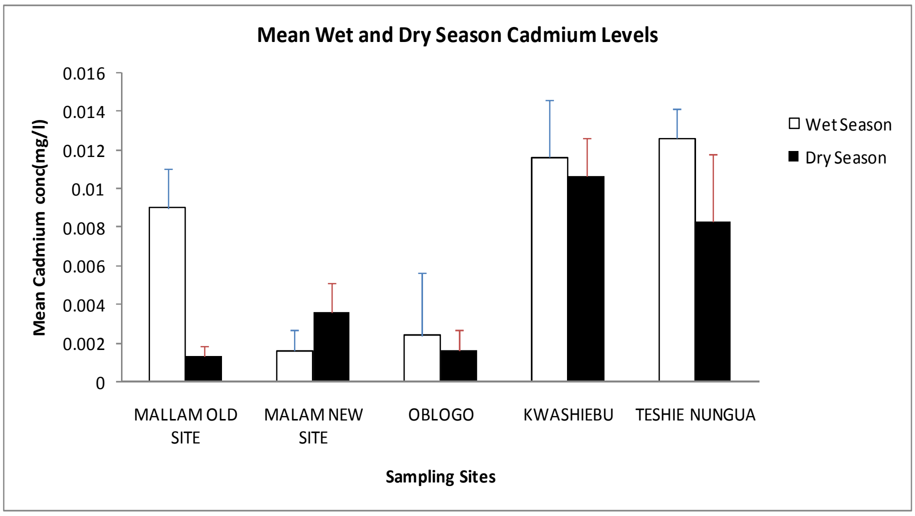


Fig. 2: Mean Seasonal Cadmium Content in Leachate at the sites

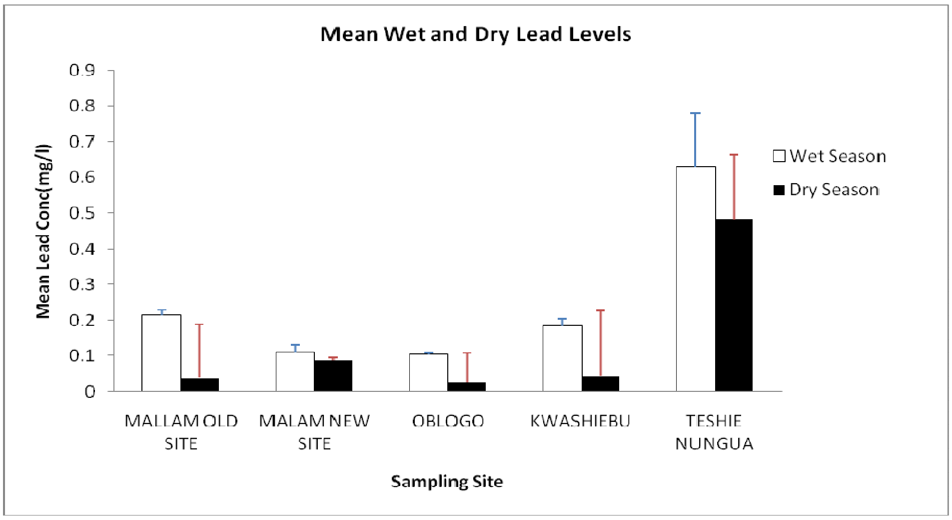


Fig. 3: Mean Seasonal Lead Content in Leachate at the Sites

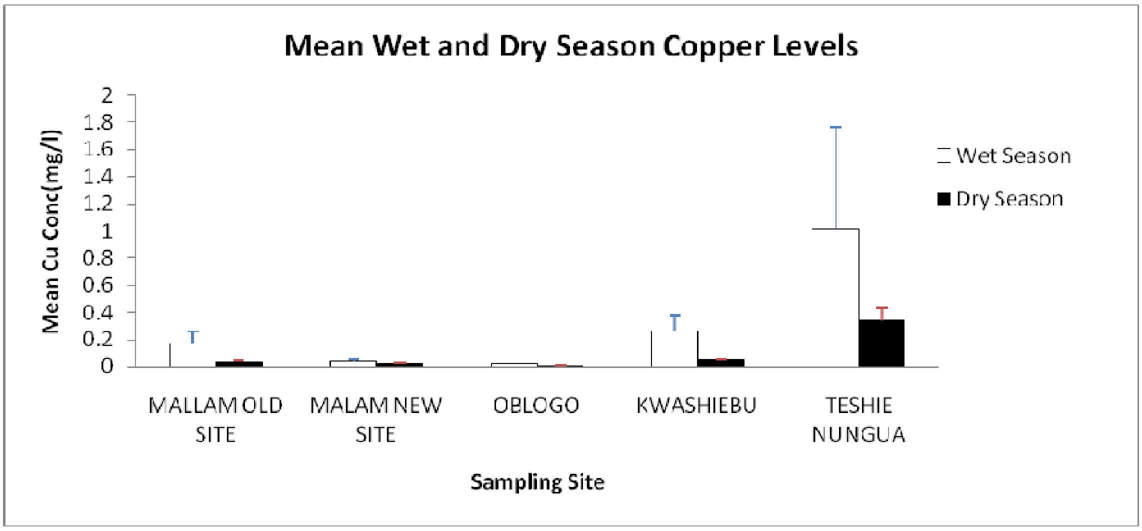


Fig. 4: Mean Seasonal Copper Content in Leachate at the Sites

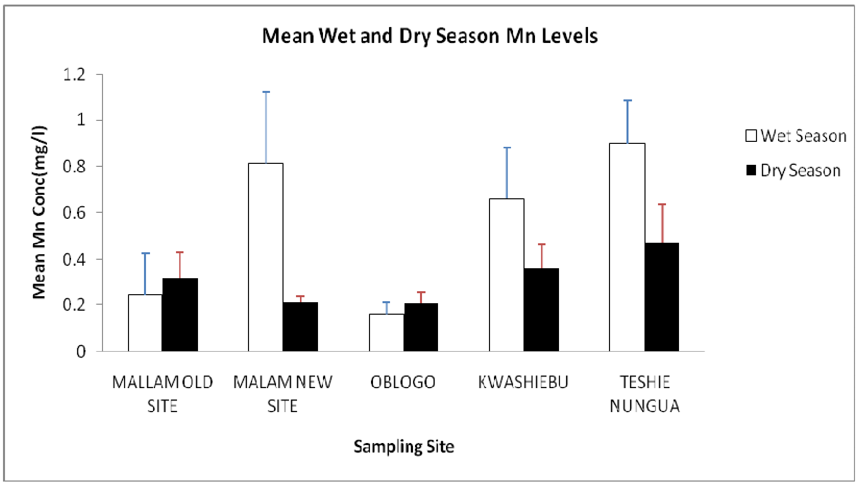


Fig. 5: Mean Seasonal Manganese Content in Leachate at the Site

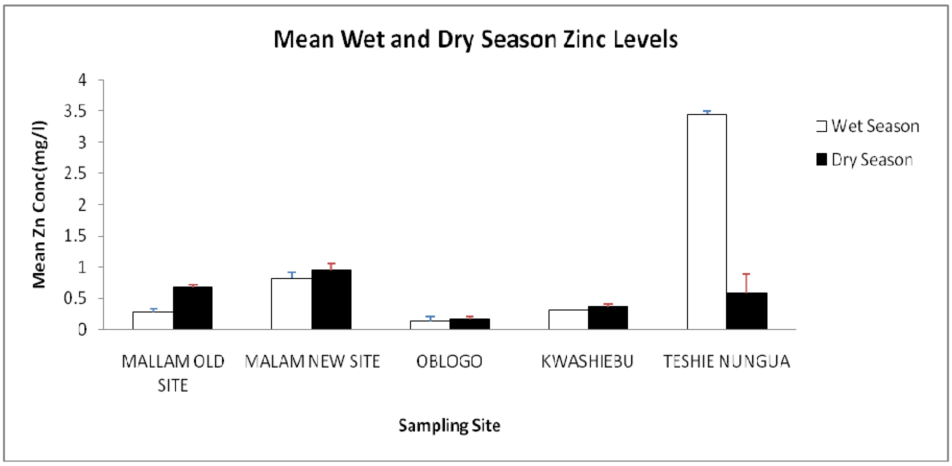


Fig. 6: Mean Seasonal Zinc Content in Leachate at the Sites

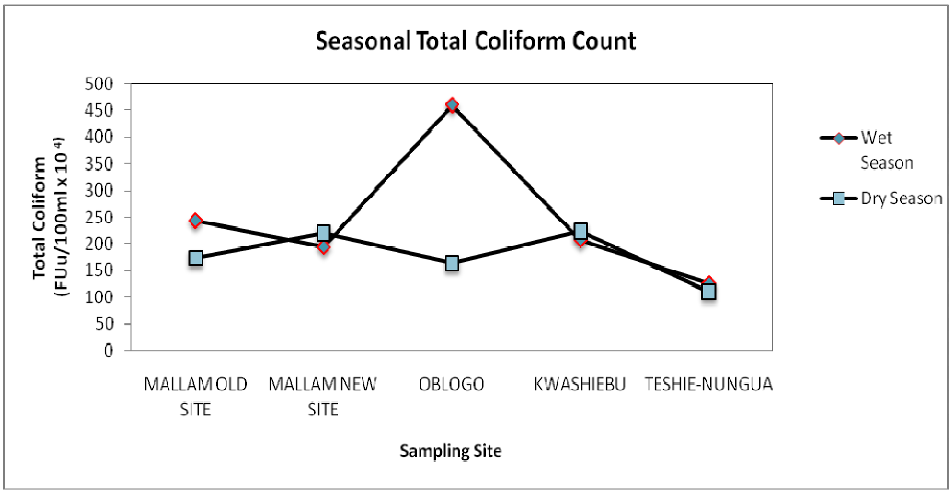


Fig. 7: Wet and Dry Season Total Coliform Population in Leachate Samples.

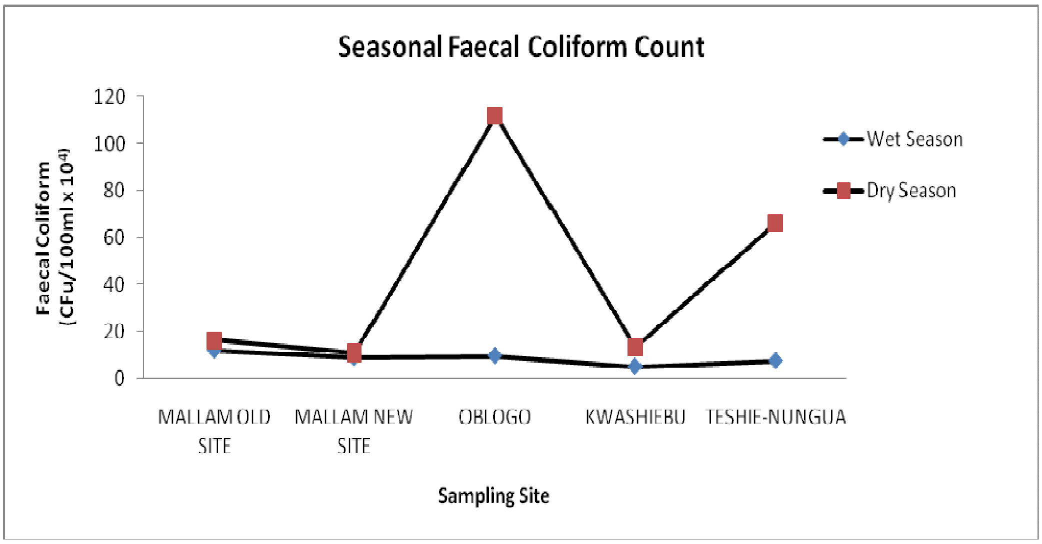


Fig. 8: Wet and Dry Season Faecal Coliform Population in Leachate Samples.

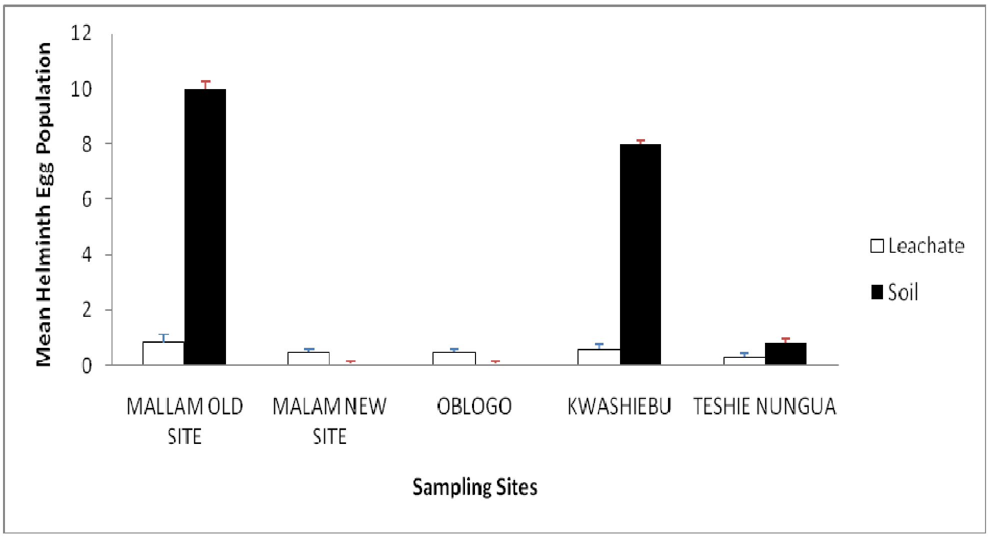


Fig. 9: Mean Helminth Egg Population of Leachate and Soil