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# Assessment of environmental degradation of soil and groundwater: A case study of waste disposal in Benin West Moat - Ekenwan gully Benin City, Edo State, Nigeria

**Christopher N Akujieze[1]* and Emmanuel E. I. Irabor[2]**

[1]Department of Geology, Faculty of Physical Sciences, University of Benin, Benin City, Edo State, Nigeria.
[2]Department of Chemistry, Faculty of Physical Sciences, University of Benin, Benin City, Edo State, Nigeria.

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**The ancient Benin moat of 2.00 to 5.00 m width, and 10 to 30 m depth almost concentrically dug round the City, is supposed to be an important socio-cultural artifact if well preserved. It has served its good purpose of defense and protection of the ancient Bini civilization. Now, modern urbanization pressure has defaced and is degrading the moat and its environs through house development, soil quarrying, gullying, flood catchment, and waste disposal. Because of its extent, it is pertinent to understand its pedo-geological and hydrogeological setting in order to assess the impact of the waste disposal on the soil and groundwater systems. Random; 11 soil (pool) samples at 0.0 to 0.5 m depth, and eight groundwater samples from pumping boreholes, 0.5 to 10.0 m on both sides of the moat were drawn. Samples were analyzed for their chemical, heavy metal constituents (including microbial in water). Comparisons of means with pristine locations in previous studies were conducted using one way analysis of variance (ANOVA) at 5% α level of significance. Results reveal contamination of soil with Al, Cd, Fe, Pb and THC at P<0.05. The groundwater also is polluted with presumptive coliform of 1.0 x $10^2$ to 1.5 x $10^3$ cfu/$ml^{-1}$ and heavy metals; Al, Cd, and Pb at P<0.01 indicating high significant difference. This indicates that the once protective moat is now a likely area of phytotoxicity and general environmental toxicity to man if chronic exposure is allowed by continual waste disposal.**

**Key words:** Wastes disposal soil and groundwater contamination in Benin West-Moat, case of environmental toxicity.

## INTRODUCTION

Urban degradation is drawing concern in Nigeria. In Edo state, it has been estimated that land loss due to gully erosion, sheet - rill erosions constitute about 5% degraded land (Ehiorobo and Izonyon, 2011). One of the most basic but non-renewable resource is soil and once lost, it is difficult and costly to replace within near future.

*Corresponding author. E-mail: christopher.akujieze@gmail.com.

A visible form of environmental degradation is waste disposed through open surface landfills or open dumps. These can be cleared up, the land cleaned up but a most visible and potentially dangerous environment degradation includes soil erosion and gully sites used as waste dumping points. Both soil and groundwater qualities can be costly and challenging to remediate or recover (Akujieze, 2006; Akujieze and Ezomo, 2010).

Gully erosion gnaws away massive earth system of an area, apart from geomorphological distortion, it opens up the geology and renders the groundwater systems highly vulnerable to contamination and pollution (Akujieze, 2004), especially when such open sites are used for waste disposal.

Typical example is the Benin West moat - Ekenwan gully that terminates at the headwater of Ogba River from where deep gully of about 1 km long had developed along the river valley. The situation in Benin City is that gully sites and the ancient Benin Moat often (10 to 30 m) deep and 2.00 to 5.00 m wide had been converted to flood channels and receptors to all types of wastes that vary from domestic, agricultural to industrial wastes. For decades, the moat has suffered erosion, gullying, sand quarrying and waste filling due to the pressure of urbanization. Some of the moat segments are perennially waterlogged with waste dumps with residential homes abounding along and around the moats. Some of the residential houses source their domestic water supply through boreholes not sufficiently distant from the moats.

The degradation effects of the use of Benin Moat - Ekenwan gully as waste disposal sites need to be investigated with particular reference to the soil and groundwater system to ensure safety of health and human life in the Urban City of Benin.

This study was aimed at determining the level of contamination of soil and groundwater by the waste disposal into moats/gully sites and environs. This would provide data for further environmental management, through effective waste disposal and groundwater protection for the area.

## MATERIALS AND METHODS

The Benin West moat is a partially concentric open trench system dug in ancient times as defensive perimeters round the capital city-seat of power of the ancient Bini Kingdom. It consists of the North, South, East and West sectors. The one under study is the Western sector here referred to as Benin West Moat.

Focus of data acquisition was on map of the surface outline, geology of the Benin West Moat-Ekenwan gully area, the soil chemistry and the groundwater setting including the groundwater quality.

In determining the surface outline, geomorphology, geology and groundwater disposition of sub-basin of the Benin West moat: topographic map of Benin City sheet 258 on scale 1:50,000 was digitalized and gridded on mesh size of 500 m (Figures 1 and 2). Mapping was conducted for more precise spatial location and tracing of moat outline, roads, streets, soil and geological features. Horizontal and vertical height, measurements of positions were made using tapes and geographic positioning systems (GPS - Gemini model). Moat top surface, wall sides and bottom heights dimensions were recorded. Soil and rock horizons with depth were correlated to obtain a stratigraphic setting of the moat-gully system. Water table depths were determined to understand how close the water table is to the floor/bottom of the gully/moat (Figure 3).

The West Moat Ekenwan-Ogba River gully system lie within latitudes (6° 23′ 00″ - 6° 19′ 00″) N and longitudes (5° 34′ 00″ - 5° 36′ 00″) E in Egor-Oredo local government area of Benin City, covering an estimated area of 64.0 × $10^6$ m (Figure 3). The Benin Westmoat traces the western sector of ancient Bini moat. It is traced from an area around Eghosa Grammar School, Okhoro - New Lagos Road Junction, then 800 m westerly across Ebo Street, then southerly besides Iyoha Road for about 1400 m to Textile Mill Road besides which it stretches westerly for about 1500 m into Aruosaghe Road. From there the moat continues southwesterly for another 2000 m across Siluko Road, Erhumwense, 2$^{nd}$ Cemetery Road in Owina Street and is routed for another 1800 m across Ekenwan-Geli-Geli-Sea port Road. The Ekenwan-Ogba gully system intensifies threatening to cut the road, at Ogba River/Spring head area and routes southerly for a distance of about 1005 m along the Ogba River valley. The Ogba River drains in a southerly direction (Figures 1, 2 and 3).

Random soil/sediment sampling was conducted by taking samples from the top 0.0m -0.5m moat/gully and >0.5 to 4.0 m at moat bottom/floor using hand auger, trowel and shovels. Disturbed soil samples were taken into polythene bags, sealed labeled and sent to Macgill Engineering for physicochemical and heavy mineral analysis whose mean results were compared with mean values of control samples of Anoliefo et al. (2001) and Akujieze (2004) to assess soil if contamination had occurred as a result of waste disposal into the moat and gully environs. These mean values were subjected to one-way statistical analysis of variance (ANOVA) at α of 5% significant level. Eight (8) groundwater samples were randomly drawn from residential pumping wells 0.5 to 10.0 m at both sides of the moat. Samples were drawn after two volume of well water was wasted. Groundwater samples for microbial tests were filled into sterile glass bottles and immediately sealed, while samples for dissolved metals were filled into 2 l PVC bottles, previously soaked in 10% nitric acid, rinsed with dilute ionized water and sealed. All the water samples were labeled and stored in iced coolers (0 to 4°C) and taken to the laboratory for analysis. Concentrations of Cr, Fe, Cu, Al, Cd, Zn, Pb and Mn were determined calorimetrically using 2D spectrophotometer. In determining the quality of groundwater, World Health Organization WHO (2011) and NIS (2007) permissible limits were used for comparison of chemical parameters. To understand groundwater contamination level, a one-way statistical comparison of means of heavy metal concentration through analysis of variance (ANOVA) at α of 5% significant level was conducted on the mean values of the present work and those of Akujieze (2004) and Akujieze and Oteze (2007), some four distant boreholes taken randomly far away from the moat - gully environment.

### General geology

The study area is underlain by sedimentary Benin Formation which has been described severally in Short and Stubble (1967), Akujieze (2004), Akujieze and Oteze (2006).

Drifts and soil-cover characterized the formation over lateritized reddish brown clayey sand capping highly porous friable white sands, pebbly sands and clay stringers with basal indurated ferruginous pebbly - coarse grained sandstone. The Benin Formation is poorly bedded and occasionally cross - bedded at greater depths. Detailed geology and lithostratigraphy of Benin Formation are illustrated in Tables 1 and 2 and Figures 1, 2 and 3.

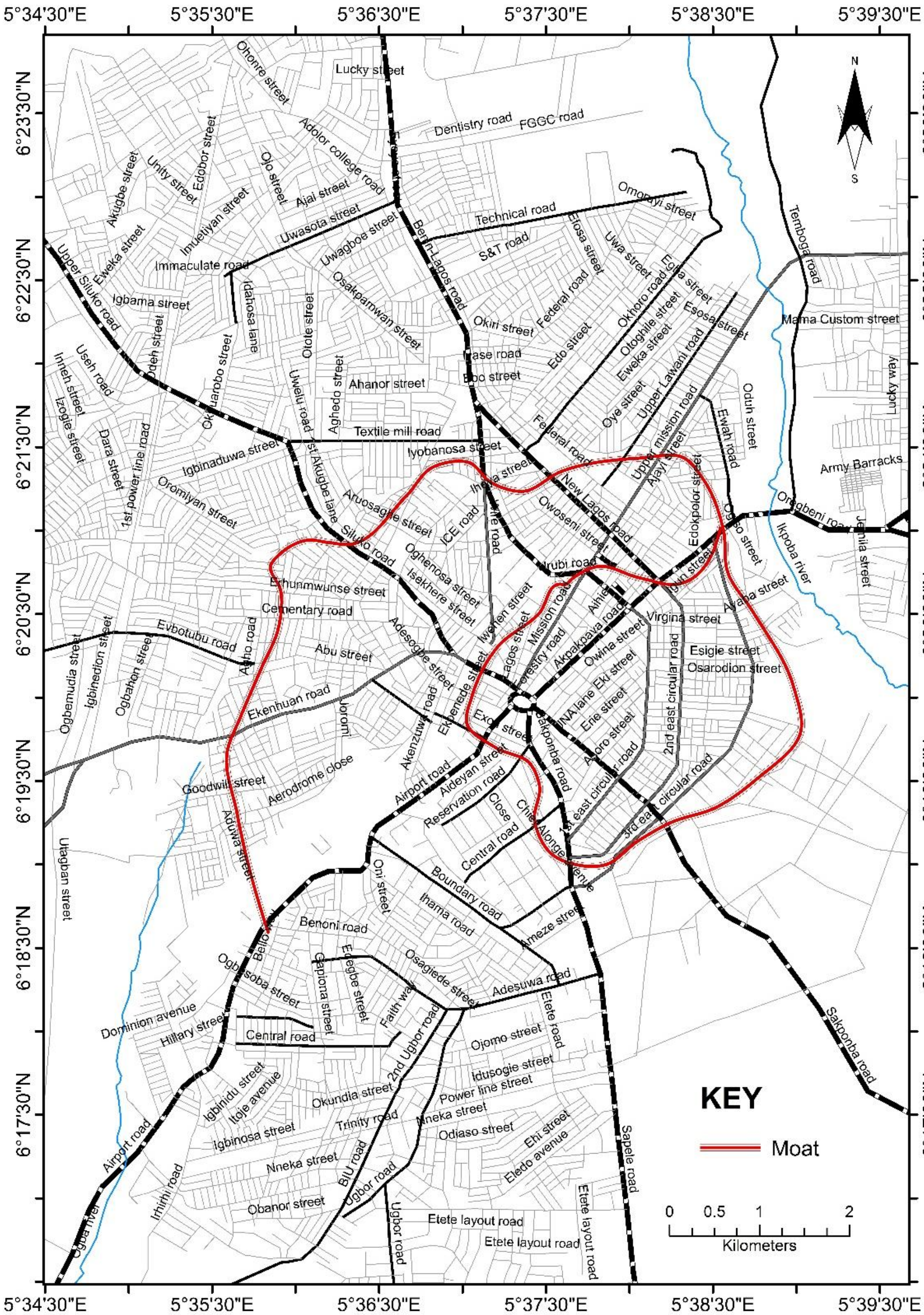



**Figure 1.** Map of Benin City town showing moat system.

## RESULTS AND DISCUSSION

The Ekenwan gully geology is illustrated in Figure 3. The sedimentary units as shown in borehole lithology logs belong to the Benin Formation. It is remarkable that the logs revealed unconfined aquifer system are devoid of clayey stringers, which is significant in giving way to free downward percolation of water bearing contaminants (of heavy metals) into and across the water table.

The Ogba spring head is the target area for ground-water source in Ekenwan area of Benin. The area host a nest of boreholes serving Benin City Public water works. The water table there lies at 0.3 - 3.0 m below the ground surface with prolific yield of about 228 $m^3h^{-1}$ and

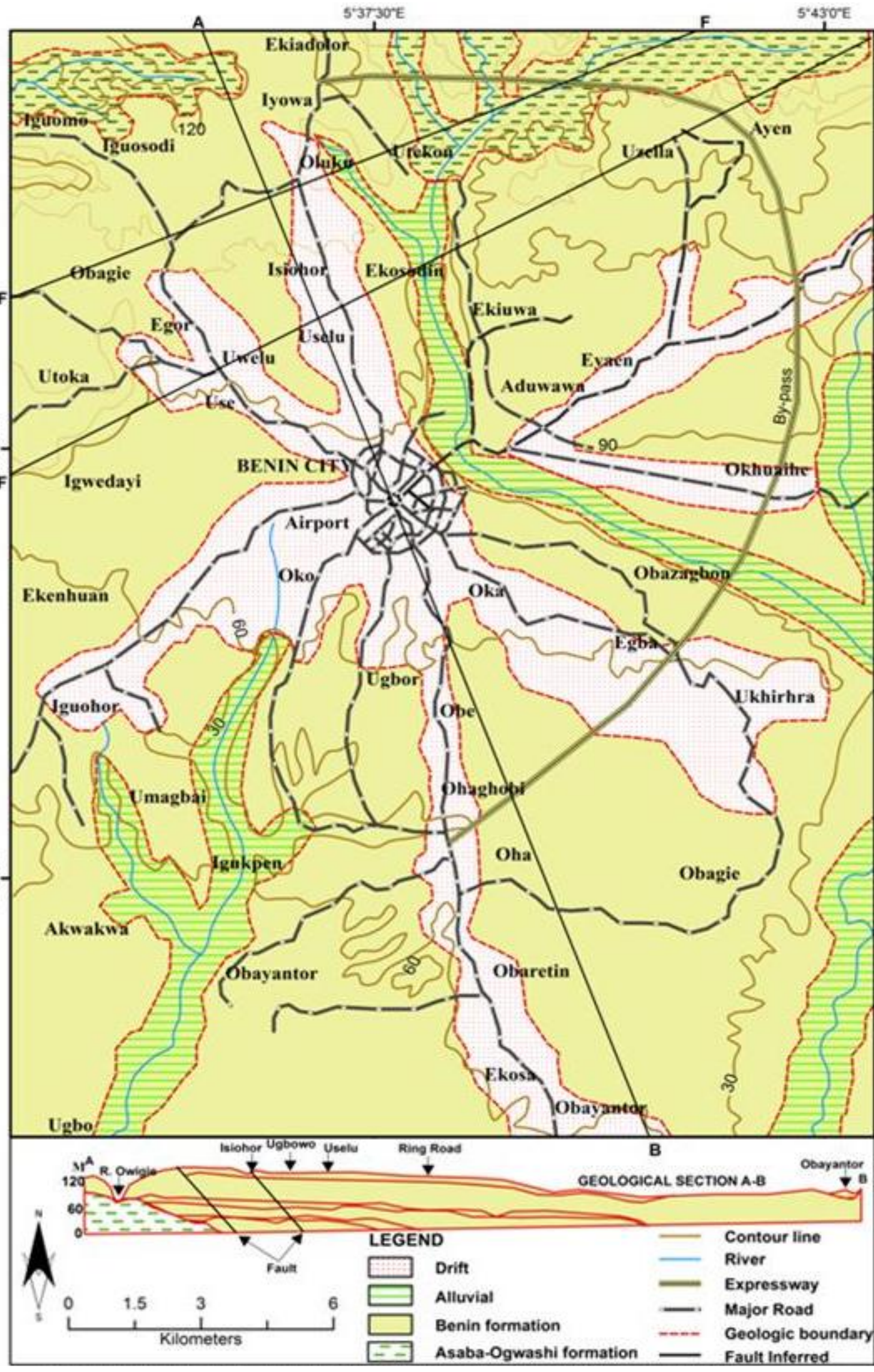



**Figure 2.** Geological map of Benin City and environs (Akujieze, 2004).

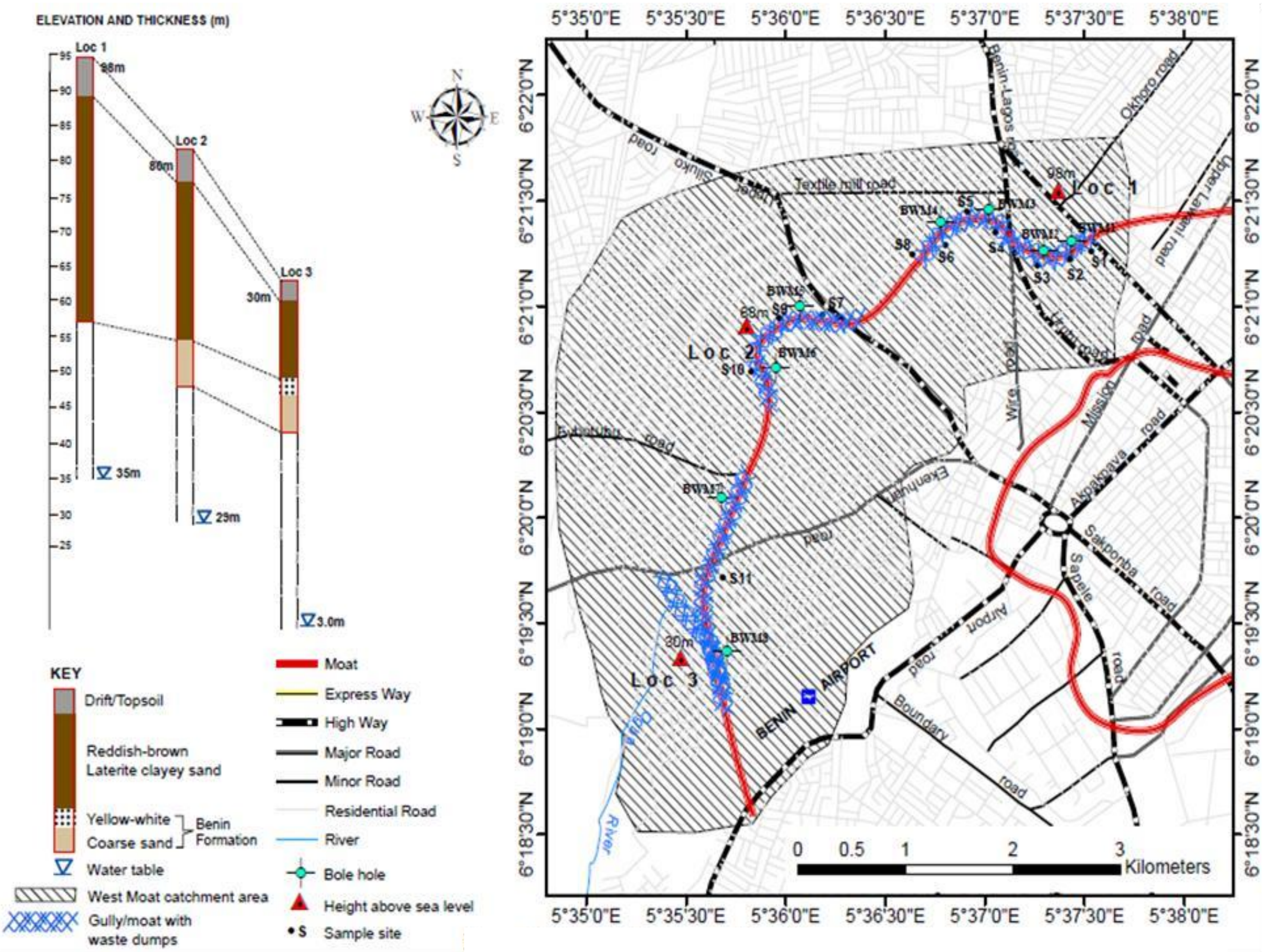



**Figure 3.** Geological section and stratigraphy of Benin west moat.

**Table 1.** Geology and Hydrostratography of Benin West Moat - Ekenwan Gully.

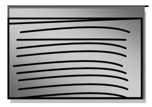
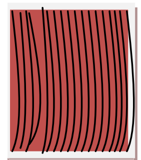
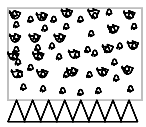
| Sedimentary unit | Lithological description |
|---|---|
| Drift | Loose light gray-dirty white sands, silt, mudflows |
| Alluvium (Only at River Banks) | Light gray - brown - dirty white sands, silt, clays gravels and pebbles. |
| Benin Formation | Top reddish brown clay sand, capping thick sequences of poorly bedded friable - loose sand gravelly - pebbly sand and pinkish - white clay stringers. |
| Asaba-Ogwashi (Azagba-Ogwashi Formation) | Dark gray-woody clay, alternating with dark clay and lignite. |

draw-down of 6.7 m (Akujieze and Oteze, 2006).

## Soil quality

Tables 3 and 4 illustrate the soil chemical and heavy metals constituents of Benin West moat and Ekenwan Gully waste dumpsites. The background soil quality is taken from Anoliefo et al. (2001) while the control for the heavy metal constituents is taken from Akujieze (2004). The justification for these backgrounds is because of the following reasons: (1) They are prestine un-impacted locations within Benin City urban, (2) they are within the same tropical climatic conditions in terms of rainfall and temperature, (3) they are from the same Oxisol soil type;

**Table 2.** Typical Benin West Moat stratigraphy.

| Age | Formation | Ground elevation and thickness (m) | Section | Unit | | Rock description |
|---|---|---|---|---|---|---|
| Recent | Alleviation of top soil | 95.00 | ~~~ ~~~<br>~~~ ~~~ | 4 | Drifts | Brown gray silty sand |
| | | 94.50 |  | 3 | Top Soil | Sandy loam gray |
| Pleistocene-oligocene | Benin formation | 92.00<br>82.00 |  | 2 | Laterite | Top reddish brown clayey sand with mud crack in some places |
| | | 60.00<br>55.50<br>50.00<br>Not to scale |  | 1 | Sand | Yellow iron stained – white friable loose sand |

the reddish brown lateritic tropical soil, (4) the soil type is underlain by the same parental Benin Formation rock type. (5) Time variant monitoring advantage can be obtained to understand levels of contaminant changes. Table 3 shows that the general trend in centimoles per kilogram of soil (c mol $kg^{-1}$) in the control area is Ca>Mg>k>Na that is, mean value of Ca (0.98)>Mg (0.40)>K (0.147)>Na (0.00) but this generally accepted trend (Ellis and Mellor, 1995) is not the same in the Benin West Moat-Ekenwan gully waste dump sites where the mean concentration is as follows; Na (2.70) > Ca (2.29) > K(1.22) > Mg (0.49) indicating that Na is more prominent. This upset suggests an impact. ANOVA results show that Na mean concentration occurs at $P<0.001$ indicating very high significant difference against control mean. While Ca, Mg, K, occur at $P>0.05$ indicating no significant difference. Total hydrocarbons (THC) occur in soil samples $B_{WS}$ (7, 8, 9, 10 and 11) ranging from 0.11 to 0.24 mg/kg with an average concentration of 0.166 mg/kg which is significant. It indicates that the moat-gully site receives automobile waste products used auto oil and grease and other waste petroleum product. There is no significant difference ($P>0.05$) in the mean concentration of C (0.82%) in moat-Ekenwan gully dumpsites against (0.80%) in the control site, also (phosphorus) P (6.84 mg/kg) in moat against P (12.37 mg/kg) control mean value.

However, site-specific variation of phosphorus (P) indicates higher concentration (18.29 $mgkg^{-1}$) at shallower 0.0 to 10 cm depth of control site, than in deeper levels (Anoliefo et al., 2001). There is generally lower concentrations of C and P in soil, probably due to absence of or low organic wastes that generate C and P or due to leaching effect due to high rainfall in a predominantly sandy (791 to 94.1%) and porous soil. The Benin West moat-Ekenwan gully waste dumpsite soil has effective cation exchangeable capacity (ECEC) mean value of 3.77 (c $molkg^{-1}$) higher than control soil mean value of 2.42 c $molkg^{-1}$. Consequently, there is availability of more exchangeable $H^+$ ion of mean 0.33 c $molkg^{-1}$ above control level at $P<0.05$ indicating a significant difference.

There is higher concentration of $Al^{3+}$0.87 c $molkg^{-1}$ in the moat-gully waste dumpsites than in control soil site with mean of 0.45 c $molkg^{-1}$. This may have ensured higher acidity in the waste dumpsites of the moat-Ekenwan-gully erosion sites. According to Ellis and Mellor (1995), where exchangeable ($H^+$) ion is available in an already acidic soil, additional $Al^{3+}$ ions play important role in generating more soil acidity. The hydrogen ion concentration pH in the control soil ranging between 5.3 to 5.9 with a mean value of 5.6 is higher than the moat-gully soil sites between 3.80 to 5.5 with mean of 4.57 which is more acidic than the control at $P>0.05$ indicating a significant difference which may have been dictated by waste disposal into the environment.

Table 4 shows that there is heavy metal build-up in soil of the Moat-Ekenwan gully waste dumpsites. Fe occurs with mean concentration of 729.65 mg/kg as against 0.075 mg/kg mean in control at $P<0.001$ very high significant difference. This compares favorably well with Fe in dumpsite in Imeokparia et al. (2009b). Mn with average value of 285.11 mg/kg against control average of 0.005 mg/kg at ($P<0.001$) indicating very high significant difference. As also Ni with mean of 0.84 mg/kg; both comparing fairly well with similar work in Benin City by (Ukpebor et al., in Imeokparia et al., 2009a) as illustrated in Table 5. Cr with mean concentration of 0.28 mg/kg

**Table 3.** Chemical properties of the soils and sediments from Benin West moat - gully Sites in comparison with means of Anoliefo et al., at α 5% significant value in one way ANOVA.

| Sample Code | Depth (m) | pH | C | N | P | c molkg$^{-1}$ | | | | | | | Clay | Silt | Sand | THC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (%) | (%) | (mg/kg) | Ca | Mg | Na | K | H | Al | ECEC | (%) | (%) | (%) | |
| $Bw_{s1}$ | 0.0 - 0.5 | 4.10 | 0.22 | 0.011 | 6.79 | 1.92 | 0.56 | 0.28 | 0.14 | 0.40 | 0.56 | 3.30 | 19.9 | 1.0 | 79.1 | ND |
| $Bw_{s2}$ | 0.0 - 0.1 | 5.50 | 0.74 | 0.058 | 26.96 | 5.04 | 1.12 | 0.27 | 0.15 | 0.30 | 0.55 | 6.88 | 9.9 | 2.5 | 87.6 | ND |
| $Bw_{s3}$ | 0.0 - 0.5 | 4.30 | 0.65 | 0.047 | 3.11 | 0.72 | 0.40 | 0.26 | 0.19 | 0.20 | 1.20 | 2.97 | 19.9 | 1.0 | 79.1 | ND |
| $Bw_{s4}$ | 0.0 - 0.5 | 4.10 | 0.51 | 0.039 | 2.54 | 0.64 | 0.32 | 0.25 | 0.11 | 0.90 | 0.40 | 2.62 | 20.9 | 0.5 | 78.6 | ND |
| $Bw_{s5}$ | 0.0 - 0.5 | 3.80 | 0.35 | 0.022 | 2.77 | 0.80 | 0.64 | 0.28 | 0.13 | 0.60 | 0.50 | 2.95 | 17.9 | 1.0 | 81.1 | ND |
| $Bw_{s6}$ | 0.0 - 0.5 | 4.10 | 0.54 | 0.038 | 2.69 | 0.72 | 0.48 | 0.26 | 0.07 | 0.30 | 0.90 | 2.73 | 19.9 | 1.0 | 79.1 | ND |
| $Bw_{s7}$ | 0.0 - 0.5 | 5.00 | 0.86 | 0.067 | 17.73 | 4.40 | 0.32 | 0.27 | 0.22 | 0.10 | 0.96 | 5.31 | 13.9 | 2.5 | 83.6 | 0.11 |
| $Bw_{s8}$ | 0.0 - 0.5 | 4.70 | 1.02 | 0.085 | 4.69 | 2.48 | 0.24 | 0.27 | 0.06 | 0.30 | 0.89 | 3.35 | 8.9 | 2.0 | 89.1 | 0.24 |
| $Bw_{s9}$ | 0.0 - 0.5 | 4.90 | 1.15 | 0.093 | 3.51 | 3.20 | 0.16 | 0.28 | 0.07 | 0.10 | 1.58 | 3.81 | 4.4 | 1.5 | 94.1 | 0.18 |
| $Bw_{s10}$ | 0.0 - 0.5 | 4.80 | 1.24 | 0.034 | 6.81 | 1.90 | 0.67 | 0.35 | 0.16 | 0.41 | 1.21 | 3.32 | 19.9 | 1.0 | 79.1 | 0.13 |
| $Bw_{s11}$ | 0.0 - 0.5 | 5.00 | 1.75 | 0.042 | 3.68 | 3.40 | 0.58 | 0.29 | 0.18 | 0.35 | 0.89 | 4.30 | 20.9 | 0.5 | 78.6 | 0.17 |
| Mean | | 4.572727 | 0.820909 | 0.04873 | 6.8436 | 2.2927 | 0.4991 | 2.70818 | 1.1245 | 0.33273 | 0.876364 | 3.776364 | 32.4 | 1.318182 | 82.645 | 0.166 |
| SD | 0.161245 | 0.523624 | 0.445252 | 0.02512 | 8.0725 | 1.558 | 0.2648 | 8.05673 | 3.2757 | 0.24017 | 0.359757 | 1.290041 | 55.84308 | 0.716684 | 5.3266 | 0.0503 |
| $K_a$ | 0-10 cm | 5.90 | 1.40 | 0.16 | 18.29 | 1.10 | 0.30 | ND | 0.19 | ND | 0.40 | 2.38 | 0.0 | 0.0 | 0.0 | 0.0 |
| $K_b$ | 10-20 cm | 5.30 | 0.20 | 0.18 | 6.50 | 0.87 | 0.51 | ND | 0.09 | ND | 0.50 | 2.46 | 0.0 | 0.0 | 0.0 | 0.0 |
| Mean | | 5.60 | 0.8 | 0.17 | 12.37 | 0.985 | 0.405 | ND | 0.14 | ND | 0.45 | 2.42 | 0.0 | 0.0 | 0.0 | 0 |
| KS-D | | 0.424264 | 0.848528 | 0.01414 | 8.3014 | 0.1626 | 0.1485 | ND | 0.0707 | ND | 0 | 0.056569 | 0.0 | 0.0 | 0.0 | 0 |
| P. values | | P<0.05 | P>0.05 | P<0.001 | P>0.05 | P>0.05 | P>0.05 | P<0.001 | P>0.05 | P<0.05 | P>0.05 | P>0.05 | | | | |

Control (ka, kb) of Anoliefo et al. (2001), ND = not done, P>0.05 = no significant difference, P<0.05 = least significant difference, P<0.01 = high significant difference, P<0.001 = Very high significant difference.

against control value of 0.02 mg/kg and Cu 2.2 mg/kg against control value of 0.15 mg/kg both occurring at P<0.01 indicating high significant difference respectively. Pb average of 0.92 mg/kg against control concentration of 0.22 mg/kg and Cd mean value of 0.97 mg/kg against background of 0.47 mg/kg occur at P>0.05 indicating no significant difference. There is generally low value of Pb, Cd, Cu, Cr and Ni in the waste dump site. This could be explained by the tendency of increasing acidity associated with pH changes with attendant redox activity and probable metal speciation. According to Akujieze et al. (2012) bioavailability of bounding heavy metals can be altered by changes in pH, organic matter content, and the redox status of contaminated soils.

## Chemical properties of groundwater

From the groundwater chemical constituents illustrated in Table 6, it could be observed that the hydrogen ion concentration pH varies from 6.40 to 7.06 with an average of 6.65 and may be described as slightly acidic on the average. This may be a reflection of an interaction between surface acidic soil environment and sub-surface groundwater. All the physico-chemical parameters and most chemical constituents except phosphorus and heavy metals like Fe, Pb, Cd and Al are within World Health Organization acceptance limit for potable water. Phosphorus occurs above European Economic Community (EC, 1980) permissible limit. There is presumptive coliform and Cd in all the groundwater samples, suggesting an impact from the disposal of waste into the Benin West Moat-Ekenwan Gully.

The heavy metals (Table 7) shows that Fe occurs above (WHO, 2011) permissible limit in boreholes 1, 2, 3, 4, 5 and 6 but at P>0.05 that is, no significant difference when compared with the Fe mean in Akujieze (2004). This implies that although Fe is increasing above WHO (2011) limit, its increase is generally not significant. While the mean of Cu in this work (0.0475 < 0.11 mg/l mean in Akujieze 2004) at P<0.01 indicating high significant difference and greater than mean of 0.03mg/l of Akujieze and Oteze (2007) both of which are below 2.0mg/l of WHO (2011) and so suggesting that Cu is not posing any threat of

**Table 4.** Heavy metals concentration (mg/kg) in the soils and sediment from Benin west moat-Ekenwan gully sites in comparison with means of (Akujieze, 2004) at α of 5% significant level in one way ANOVA.

| S/N | Location and Depth(m) (pool samples) | | Fe | Mn | Zn | Cu | Cd | Pb | Cr | Ni | Al |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $BW_{s1}$ | 0.0 - 0.5 | 1121.45 | 413.52 | 248.71 | 3.50 | 1.89 | 1.25 | 0.44 | 6.13 | 0.0 |
| 2 | $BW_{s2}$ | 0.0 - 0.5 | 403.50 | 217.80 | 125.60 | 2.27 | 0.0 | 0.94 | 0.32 | 5.18 | 0.52 |
| 3 | $BW_{s3}$ | 0.0 - 0.5 | 948.70 | 335.90 | 278.20 | 3.15 | 0.75 | 0.26 | 0.41 | 5.45 | 0.31 |
| 4 | $BW_{s4}$ | 0.0 - 0.5 | 621.50 | 294.20 | 180.50 | 1.84 | 0.49 | 0.39 | 0.19 | 7.40 | 0.11 |
| 5 | $BW_{s5}$ | 0.0 - 0.5 | 723.60 | 258.40 | 145.00 | 1.20 | 0.72 | 0.30 | 0.15 | 6.48 | 0.23 |
| 6 | $BW_{s6}$ | 0.0 - 0.5 | 745.70 | 286.20 | 175.80 | 1.12 | 1.65 | 0.75 | 0.14 | 4.87 | 0.40 |
| 7 | $BW_{s7}$ | 0.0 - 0.5 | 801.20 | 293.00 | 195.80 | 0.97 | 0.77 | 0.81 | 0.30 | 6.18 | 0.29 |
| 8 | $BW_{s8}$ | 0.0 - 0.5 | 723.50 | 216.80 | 140.20 | 1.36 | 0.92 | 1.74 | 0.15 | 4.31 | 0.13 |
| 9 | $BW_{s9}$ | 0.0 - 0.5 | 620.70 | 189.30 | 120.00 | 2.52 | 0.81 | 1.35 | 0.30 | 6.72 | 0.27 |
| 10 | $BW_{s10}$ | 0.0 - 0.5 | 680.50 | 250.50 | 205.50 | 3.80 | 1.81 | 1.55 | 0.41 | 6.8 | 0.35 |
| 11 | $BW_{s11}$ | 0.0 - 0.5 | 635.80 | 380.60 | 188.60 | 3.20 | 0.95 | 0.83 | 0.30 | 4.8 | 0.28 |
| Mean | | | 729.65 | 285.1109 | 182.1736 | 2.266364 | 0.978182 | 0.924545 | 0.282727 | 5.847273 | 0.262727 |
| SD | | | 186.5758 | 69.72868 | 49.67139 | 1.035657 | 0.580031 | 0.501326 | 0.111184 | 0.984348 | 0.143881 |
| $K_{OT}$ | | 0.0 - 0.2 | 0.13 | 0.01 | 0.33 | 0.13 | 0.04 | 0.19 | 0.01 | 0.0 | ND |
| $K_{OB}$ | | 0.2 - 0.5 | 0.02 | 0.0 | 0.33 | 0.18 | 0.90 | 0.25 | 0.03 | 0.0 | ND |
| Control Mean | | | 0.075 | 0.005 | 0.33 | 0.155 | 0.47 | 0.22 | 0.02 | 0 | ND |
| SD | | | 0.055 | 0.005 | 0 | 0.025 | 0.43 | 0.03 | 0.01 | 0 | ND |
| P. value | | | P<0.001 | P<0.001 | P<0.001 | P<0.01 | P>0.05 | P>0.05 | P<0.01 | P<0.001 | P<0.05 |

$K_{OT}$, $K_{OB}$ = Control values of Akujieze (2004), ND = not done, P>0.05 = no significant difference, P<0.05 = least significant difference, P<0.01 = high significant difference, P<0.001 = very high significant difference.

**Table 5.** Concentration of Heavy Metals Mg/kg in Top Soil Samples in Refuse Dumps in Benin City. Adapted from; Imeokparia et al. (2009).

| Dump site location | Distance from dump site (m) | Metal concentration mg/kg | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Zn | Ni | Cu | Pb | Cr | Cd | Mn | Fe |
| Iyaro | 0.00 | - | 130±3.3 | 30±1.0 | 159.54±14.22 | 120±3.30 | 10.0±1.20 | 294.5 | - |
| | 50.0 | - | 11.4±7.0 | 13.25±1.02 | 26.4±1.98 | 11.15±1.3 | 10.0±1.14 | 40±1.58 | - |
| Siluko | 0.00 | - | 708.0±17 | 16.7±0.64 | 63.90±2 | 24.0±2.3 | 29±0.98 | 344±15 | - |
| | 50.0 | - | 62.0±2.0 | 11.05±1.22 | 4.8±0.09 | 9.2±0.94 | 6.9±0.82 | 211±11.46 | - |
| West Circular | 0.00 | - | 54.0±1.74 | 30.0±2.36 | 80±3.22 | 35.0±3.0 | 7.30±0.99 | 228±4.4 | - |
| | 50.0 | - | 15.11±1.10 | 5.9±0.64 | 18.0±1.30 | 6.15±0.8 | 5.00±0.78 | 54.0±2.27 | - |

**Table 6.** Physiochemical parameters of groundwater along Benin West moat-Ekenwan gully sites Benin City.

| S/N | Sample location | Colour Hazen | Turbidity(UTC) | Conductivity µScm$^{-1}$ | Total solid mg/l | pH | Alkalinity (mg/l) | Total hardness (mg/l) | Chloride (Cl) mg/l | Nitrate ($NO_3$) mg/l | Sulphate ($SO_4$) mg/l | Phosphate ($P_2O_4$) mg/l | Sodium (Na) mg/l | Potasium (K) mg/l | Calcium (Ca) mg/l | Magnesium (Mg) mg/l | Iron (Fe) mg/l | Chromium (Cr) mg/l | Copper (Cu) mg/l | Zinc (Zn) mg/l | Lead (Pb) mg/l | Cadmium (Cd) mg/l | Aluminium (Al) mg/l | Presumptive coliform cfu/ml | E.coli |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Bwm_1$ | Ebo Street | 3.0 | 0.0 | 47.60 | 38.10 | 6.50 | 18.30 | 13.00 | 36.21 | 0.30 | 1.80 | 1.20 | 1.18 | 5.80 | 2.81 | 1.46 | $0.11^+$ | 0.030 | 0.05 | 0.06 | 0.01 | 0.01 | 0.55* | $1.2\times10^{3+}$ | 0.0 |
| $Bwm_2$ | Eyobo area | 3.0 | 0.0 | 49.90 | 40.90 | 6.60 | 24.40 | 24.40 | 26.63 | 0.25 | 1.70 | 1.90 | 3.04 | 6.70 | 8.42 | 0.73 | $0.15^+$ | 0.021 | 0.04 | 0.04 | 0.02* | 0.02 | 0.01 | $1.0\times10^{2+}$ | 0.0 |
| $Bwm_3$ | Idugboe area | 1.0 | 0.0 | 165.60 | 132.50 | 6.60 | 73.20 | 13.00 | 39.76 | 0.40 | 1.20 | 1.45 | 6.24 | 5.90 | 2.49 | 0.24 | 0.03 | 0.022 | 0.03 | 1.82 | 0.02* | 0.01 | 0.65* | $1.3\times10^{3+}$ | 0.0 |
| $Bwm_4$ | Ehaikpen | 0.0 | 0.0 | 96.10 | 77.10 | 6.50 | 24.40 | 23.00 | 35.86 | 0.20 | 1.30 | 1.80 | 1.88 | 4.33 | 5.61 | 2.19 | $0.25^+$ | 0.036 | 0.03 | 1.34 | 0.01 | 0.01 | 0.48* | $1.4\times10^{3+}$ | 0.0 |
| $Bwm_5$ | Owigie | 2.5 | 3.2 | 150 | 128 | 6.40 | 70.5 | 23.8 | 28.5 | 0.45 | 1.65 | 1.66 | 1.88 | 6.85 | 8.30 | 0.89 | $0.16^+$ | 0.035 | 0.05 | 1.36 | 0.01 | 0.01 | 0.46* | $1.4\times10^{3+}$ | 0.0 |
| $Bwm_6$ | Owina | 2.5 | 2.8 | 160 | 130 | 6.60 | 30.2 | 23.5 | 29.8 | 0.35 | 1.70 | 1.59 | 2.65 | 5.66 | 7.20 | 1.56 | $0.18^+$ | 0.036 | 0.06 | 0.04 | 0.01 | 0.02 | 0.30* | $1.3\times10^{3+}$ | 0.0 |
| $Bwm_7$ | Erhumse | 3.0 | 3.75 | 70 | 0.0 | 7.00 | 40.14 | 0.0 | 16.00 | 0.66 | 0.9 | 0.60 | 9.27 | 8.60 | 10.00 | 14.60 | 0.03 | 0.030 | 0.06 | 0.70 | 0.04* | 0.02 | 0.48* | $1.5\times10^{3+}$ | 0.0 |
| $Bwm_8$ | Evbotobu | 3.0 | 2.00 | 90 | 0.0 | 7.06 | 36.76 | 0.0 | 20.00 | 0.50 | 0.6 | 0.99 | 4.00 | 4.20 | 5.00 | 4.60 | 0.04 | 0.04 | 0.06 | 0.65 | 0.03* | 0.02 | 0.55* | $1.5\times10^{3+}$ | 0.0 |
| Mean | | 2.25 | 1.47 | 103.65 | 68.33 | 6.658 | 39.74 | 15.09 | 29.10 | 0.389 | 1.357 | 1.399 | 3.77 | 6.01 | 6.23 | 3.28 | $0.118^+$ | 0.31 | 0.05 | 0.69 | 0.02 | 0.15 | 0.44 | 1212.5 | 0.0 |
| WHO 2011 | | 15.0 | 5.0 | 1,200 | 500 | 6.15-9.5 | 250.0 | 100.0 | 200.0 | 25.00 | 200.00 | $0.35^E$ | 200.0 | 12.00 | 75.00 | 30.00 | 0.1 | 0.05 | 2.00 | 3.00 | 0.01 | 0.003 | 0.20 | 10.00 | 0.0 |
| NIS 2007 | | 3.0 | 5.0 | 1,000 | 1,500 | 6.0-8.5 | 100 | 50.0 | 250.0 | 50.0 | 100.0 | - | 200.0 | 10.0 | 75.0 | 20.0 | 0.3 | 0.05 | 1.00 | 5.00 | 0.01 | - | 0.50 | | 0.0 |

$^+$Above WHO (2011) permissible limit for potable water E.E.C. (1980) Standard Limit European Economic Community. *Above WHO (2011) and NIS (2007) permissible limit for potable water.

**Table 7.** Heavy metals concentration (mg/l) and their mean values in groundwater along Benin west moat-Ekenwan Gully Sites in comparison with values from borehole sources far away from the moat in Benin City.

| S/N | Location | Fe (mg/l) | Cu (mg/l) | Zn (mg/l) | Pb (mg/l) | Cd (mg/l) | Cr (mg/l) | Al (mg/l) | Mn |
|---|---|---|---|---|---|---|---|---|---|
| $Bw_{H1}$ | Ebo Street | 0.11 | 0.05 | 0.06 | 0.01 | $0.01^+$ | 0.030 | $0.55^+$ | ND |
| $Bw_{H2}$ | Eyoba | 0.15 | 0.04 | 0.04 | $0.02^+$ | $0.02^+$ | 0.021 | 0.01 | ND |
| $Bw_{H3}$ | Idugboe | 0.03 | 0.03 | 1.32 | $0.02^+$ | $0.01^+$ | 0.022 | $0.65^+$ | ND |
| $Bw_{H4}$ | Ehaikpen | 0.25 | 0.03 | 1.34 | 0.01 | $0.01^+$ | 0.036 | $0.48^+$ | ND |
| $Bw_{H5}$ | Owigie | 0.16 | 0.05 | 1.36 | 0.01 | $0.01^+$ | 0.035 | $0.46^+$ | ND |
| $Bw_{H6}$ | Owina | 0.18 | 0.06 | 0.04 | 0.01 | $0.02^+$ | 0.036 | $0.30^+$ | ND |
| $Bw_{H7}$ | Erhumse | 0.03 | 0.06 | 0.70 | $0.04^+$ | $0.02^+$ | 0.030 | $0.48^+$ | ND |
| $Bw_{H8}$ | Evbotobu | 0.04 | 0.06 | 0.65 | $0.03^+$ | $0.02^+$ | 0.040 | $0.55^+$ | ND |
| $Mean_1$ | | 0.12 | 0.05 | 0.69 | $0.02^+$ | $0.02^+$ | 0.03 | $0.44^+$ | ND |
| STD | | 0.08 | 0.01 | 0.60 | 0.01 | 0.01 | 0.01 | 0.20 | 0.0 |
| *$B_{H30}$ | Ugbiyoko | 0.05 | 0.11 | 1.63 | 0.00 | ND | ND | ND | 0.01 |
| *$B_{H31}$ | Gapiona/Ugbor | 0.03 | 0.05 | 1.31 | 0.01 | ND | 0.01 | ND | 0.01 |
| *$B_{H35}$ | Egor | 0.03 | 0.12 | 0.32 | 0.01 | ND | ND | ND | 0.01 |
| *$B_{H39}$ | GRA/Ugbor | 0.02 | 0.16 | 0.98 | 0.01 | ND | ND | ND | 0.03 |
| *$Mean_2$ | | 0.0325 | 0.11 | 1.06 | 0.0075 | ND | 0.0025 | 0.00 | 0.015 |
| P. value | | P>0.05 | P<0.01 | P>0.05 | P>0.05 | P>0.05 | P<0.001 | P<0.001 | P<0.001 |
| $Mean_3^{\#}$ | | 0.08 | 0.03 | 0.40 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 |
| WHO 2011 | | 0.1 | 2.0 | 3.0 | 0.01 | 0.003 | 0.05 | 0.20 | 0. |

*Akujieze (2004), #Akujieze and Oteze (2007). $^+$Above WHO (2011) permissible limits for potable water. ND = Not done, P>0.05 = No significant difference, P<0.05 = least significant difference, P<0.01 = high significant difference, P<0.001 = very high significant difference.

contamination. The same with Zn which occurs at P>0.05; no significant difference in the mean concentration of 0.688 mg/l against 1.06 mg/l of Akujieze (2004) and 0.40mg/l (Akujieze and Oteze, 2007) all < 3.0 mg/l of WHO (2011). Pb occurs at the threshold of 0.1 mg/l in almost all the groundwater samples, and groundwater from boreholes 2, 3, 7 and 8 contain Pb concentrations above (WHO, 2011) permissible limits. With the mean occurring at P>0.05, no significant difference; it implies that the aquifer is receiving a uniform influx of Pb, signaling potential Pb pollution with time if the source(s) of input (probably diffused) remain(s) unchecked. Cd occurred above (WHO 2011) 0.003 mg/l in all the eight groundwater samples at P<0.001 indicating very high significant difference. Al occurred at above WHO (2011) permissible limit of 0.2 mg/l in groundwater samples from boreholes 1, 3, 4, 5, 6, 7 and 8.

## Conclusion

It is evident that waste disposal into the Benin West Moat - Ekenwan gully sites impacted soil and groundwater in the environment; by acidifying the soil pH and contaminating the soil with Fe, Pb, Cd and Al. The presence of total hydrocarbon THC (0.166 mg/l) can be critical if allowed to continue because of dangers of possible chlorination under the humid environment. Al in the waste dumps at P<0.05 when compared with other control means is significant and was reported by Anoliefo et al. (2001) in another location in Benin City, where high accumulating of Al in soil caused high phytotoxicity inhibiting root growth and plant uptake of water and nutrients. Al, Pb, Cd, are not only high in soil but also in groundwater of this study area where Al and Cd occur at P<0.001 in ANOVA comparison of means with reference means from other works in Benin City at α of 5% indicating very high significant difference. Apart from the phytotoxicity, long exposure of Al, Pb, Cd, Cu, Cr and Mn to man can pose serious health hazards. According to Erah et al. (2002), chronic exposure of man to Pb can cause Pb-poisoning, interference in red-blood cell chemistry, nervous system damage, mental defects, and IQ depressions in children. Cd in man and animals causes kidney and liver dysfunction, hypertension and heart diseases. Solutions include: (1) greater public awareness against indiscriminate waste disposal into the moats, (2) Clearing the moat of waste, (3) soil recovery and remediation, and (4) groundwater treatment and aquifer remediation. The handicap in this study includes lack of facilities for greater understanding of the speciation processes of the heavy metals in the waste soil. Therefore, there is need for provision of facilities and funds for more studies to facilitate soil/groundwater interaction for better groundwater quality monitoring to understand metal mobility and contamination toward better control and environmental management for soil and groundwater conservation.

## Conflict of Interests

The author(s) have not declared any conflict of interests.

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