Analele Universităţii din Oradea, Seria Geografie **XXVIII**, no. 2/**2018**, pp. **245-254**
ISSN **1221-1273**, E-ISSN **2065-3409** Article no. **282110-790**

CHARACTERISTICS OF MICRO-DRAINAGE SYSTEM AND ITS ENVIRONMENTAL IMPLICATIONS IN URBANIZED TROPICAL CITY OF ILORIN, NIGERIA

Kayode IROYE[*]
Department of Geography and Environmental Management, University of Ilorin, Nigeria,
e-mail: kayodeiroye@gmail.com

Abstract: The importance of micro drainage infrastructure, especially in rapidly growing cities cannot be over-emphasized. It is needed to evacuate storm runoff and household sewage to the natural drainage in order to prevent flooding and pollution; and promote public health and safety. The efficiency and effectiveness of this drainage infrastructure however depend on their distribution, size, and integration with the natural drainage. In this study, the effect of drainage capacity expressed as a product of length, width and height on efficiency and effectiveness have been explored. Data used were sourced from the field personally by the researcher during the peak period of rainy season in year 2015. Result obtained indicates that the dimension of the drainage channels are just too small for efficient transmission out the city, the increased runoff discharge brought about by increased frequency and intensity of rainfall induced by climate change and catalyzed by rapid rate of urbanization in the study area. People's poor solid waste generation and disposal attitude was also observed as one of the problems confronting the effectiveness of micro drainage in the study area; this is because sediments of various types were found reducing flow efficiency in the drainage channels. Methods that can be used to effectively manage the drainage channels were subsequently recommended.

Key words: Micro-drainage, Infrastructure, Urbanization Sedimentation Carrying capacit

* * * * * *

INTRODUCTION

Urban drainage is managed through two systems of micro and macro drainage infrastructure. The micro drainage relates to conduits constructed for conveyance of water from urban paved surfaces. Such a system according to Miguez and Rezende (2012) is essentially defined by the layout of streets in urban areas. The macro-drainage on the other hand, refers to the main drainage network within a catchment; this can either be natural such as rivers and streams or complimentary engineering works such as canals, storm water galleries or dikes. Such features receive and discharge out the catchment, the surface runoff earlier taken by the micro drainage system. The macro drainage system within a catchment typically has a wider area in which to flow; within such a system tress and small log or debris jam can be easily accommodated by minor diversions of flow without causing problems. As a matter of fact, the presence of vegetation and

[*] Corresponding Author

minor obstructions in macro drainage systems that cause riffles and pools are desired because they aids in the improvement of such habitat and water quality. Unlike the macro system however, the micro drainage system is typically designed to use less surface area to carry more water. Such system thus needs more attention as regards their operation because there is no room to carry overflows which can either result from blockages or sedimentation.

The main purpose of urban drainage according to United Nations center for Human Settlement Report (1991) is to convey storm water to the receiving waters with a minimum of nuisance, danger and damage. According to the report, goals of urban drainage management include:

I. ensuring that floodwater inundation of commercial, residential and industrial areas located in flood-prone landscape occurs only on rare occasions and that the velocity/depth of conditions during these events are below prescribed limits;

II. providing convenience and safety for pedestrians and traffic by controlling storm water flows within prescribed limits; and,

III. retaining within each catchment as much incident rainfall and run-off as is possible given the planned use of the catchment terrain and its biotic and engineering characteristics.

However, reports from studies of many urbanized settlements, especially in developing nations are not indicating the achievement of the above enumerated objectives. Studies such as (Aderogba et al., 2012; Aid, 2006; Ajibola et al., 2012; Dodman et al., 2007; Frimpong, 2014; Herman, 2009, 2010; Iroye, 2008; Omole and Isiorho 2011; Tucci, 2001) indicates that urban areas in developing countries, most times present risk of flooding following rainfall event. Reasons given for the extreme hydro meteorological hazards of flood in the region include rapid urbanization leading to land pavement, inappropriate solid waste generation and disposal methods, lack of development planning and climate change. According to Silveira (2002), problems of urban drainage management is more serious in the developing countries than developed nations because urban developments in the region are occurring under more difficult socio-economic, technological and climatic conditions.

Though the above reasons adduced for flooding, especially in urban centres in developing countries are germane, the frequency and intensity of flood disasters in the region differ from one urbanized area to another due to nature and conditions of micro drainage infrastructure (Mathingly, 1995; Jimoh, 2008; Iroye, 2013). Aina et al., (1994) described the condition of micro drainage system in Lagos, Nigeria which exemplifies most urban centres in developing countries thus: “In many areas, roads have been built without complementary gutters for rainwater. Where a drainage system exists, it is often not properly constructed and maintained. The lack of solid-waste collection compounds the problem as wastes block gutters and drains. In addition, many buildings have been erected in ways that block storm water routes. Little attention is given to clearing the drains in advance of periods of the year when rain is expected”.

Availability of an efficient and effective drainage infrastructure is not only vital for flood control, it is a major pre-requisite for achieving a clean and healthy environment.

Though the capacities of some of the micro drainage system may be adequate to effectively control flood when designed; changes in urban areas induced by urbanization and in storm frequency and intensity resulting from climate change are now producing higher flows in most cities that exceed their capacities. Together with water supply facilities and sewage system, urban drainage according to Silveira (2002) forms the third of three basic structures for managing water in cities. This reason thus justify urban drainage study, especially in a tropical city of a developing country where rapid rate of urbanization (figure 1) is not commensurate with investment in infrastructure. This is against a background of climate change, poor land-use planning, weak institutional framework, people’s poor attitude towards solid waste generation and disposal and weak optimization of little resources available as a result of bad management (Yilmaz, 2004; Rahman, 2004; Goldenfum, 2001).

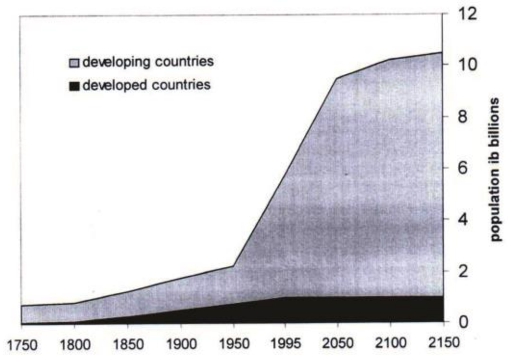

Figure 1. World Population Growth
Source: Tucci (2001)

Poor urban drainage systems apart from causing flooding, also interferes with the functioning of the entire city, affecting sanitation, housing, transport, public health among other systems (Miguez and Rezende, 2012). Though deaths due to floods, landslide and building collapse seems to be the most dramatic signs of the suffering that improved drainage can help to alleviate, noticeable and tangible are the greater impacts of the troll of disease and disability that can emanate from poor drainage (Cairncross and Quano, 1991). Attempt at managing the urban environment thus calls for study of this nature. Specifically, this study seeks to examine the characteristics of micro drainage system in the study area; compute and compare the designed capacities of the drainage channels at construction with the present capacities and analyse the composition of materials found in the channels.

THE STUDY AREA

Ilorin, the capital city of Kwara State, Nigeria is the study area for this investigation (figure 2). The city which lies between longitudes 8^0 24' and 8^0 36' north of the equator and between latitudes 4^0 10' east of the Greenwich meridian has humid tropical climate which is characterized by wet and dry seasons.

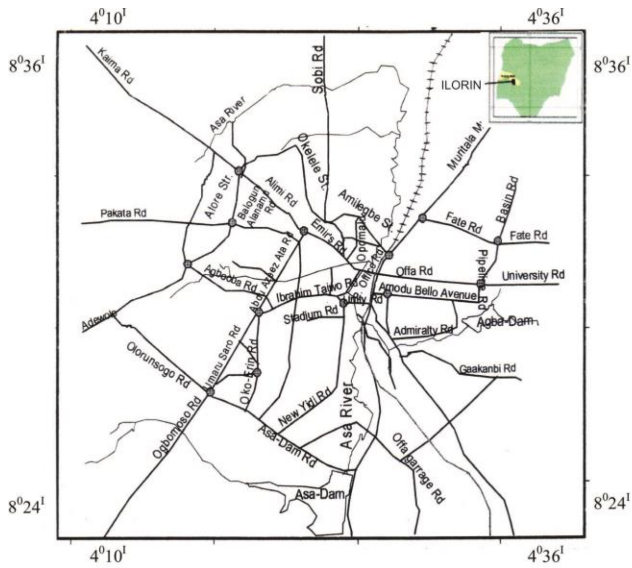

Figure 2. Street Map of Ilorin the Study Area with Nigeria as Inset
Source: Kwara State Town Planning (2000)

Wet season in the town begins towards the end of March when Tropical Maritime Airmass is prevalent and ends in October, often abruptly. Dry season in the town begins with onset of Tropical Continental Airmass which is predominant between the months of November and February. The mean annual total rainfall for Ilorin is 1200 mm (Olaniran, 2002). Analysis of rainfall values for the town shows that rain scarcely fall in the months of January, February, November and December (Oyegun, 1983). Rainfall concentration is usually between the months of March and October, exhibiting double maxima pattern with peak periods in the months of June and September and a period of dry spell in August. Temperature in the town is uniformly high between 25 ^{0}C and 28 ^{0}C. Ilorin is covered mainly by ferruginous tropical soil on crystalline acidic rock (Areola, 1978). The soil type has both sandy and clayey deposits lying on each other while the city is drained mainly by River Asa.

Urbanization process is fast replacing the natural surface in the town with artificial surfaces with its consequent effects on runoff generation. Oyegun (1987) observed the built up area in Ilorin to have grown from 20.40 sqkm in 1963 to about 58.00 sqkm in 1982, while the area occupied by grass, fallowland and tall covers decrease from 35.84 sqkm to 9.70 sq.km within the same period. In this same vain, Aderamo (1990) observed that urban development in the city increased from 1235.8 hectares in 1963 to 4515.8 hectares in 1988 representing almost 400% growth rate within a period of 25 years. This analysis indicates the level at which the hydrological process is being affected by urbanization process in the city.

MATERIALS AND METHODS

The study is based on data collected directly from the field during the rainy season between the months of July and September, 2015. Channel characteristics of micro drainage system along fifty four (54) road networks which total a length of 45.04 km was examined in this study. The micro-drainage characteristics examined include channel depth, width, length and capacity. While a measuring tape was used to take readings on channel depth and width, the length of each channel was computed from readings from a car speedometer. Two readings on depth were taken during the study; these are readings on depth at construction taken after clearing out the debris inside the drainage channel and current depth taken by leaving the debris inside the drainage channel. These two readings aid in the computation of drainage capacity at construction and current capacity after siltation respectively. All readings were taken at 500 meter equidistance position along each road network in the study area. At each site where measurements on channel characteristics were taken, sediments inside the channel were scouped out, separated into types and weighted in percentage. Because the road networks in the study area are mainly flanked by two drainage channels, one on each side; mean value of measurements on sediments taken from each sampling site inside both drainage channels along the road is recorded as value for such road network. However, in few cases where drainage channel only exist on one side of the road, mean value of measurements on sediments taken at each sampling site inside such drainage channel was used in this analysis as value for such a road network. The 90.08 km drainage channel length covered in this study is an ideal representative to critically expose the problems of micro drainage system in Ilorin metropolis and to provide sufficient framework for formulating practical recommendations for ameliorating problems of flooding, sedimentation and pollution which can be induced by poor drainage system.

RESULTS AND DISCUSSION

Table 1 presents the data on characteristics of micro-drainage system in the study area. The table revealed that most street networks examined in this study (90.7%) have drainage system on both sides with the exception of Airport – Garin Alimi and Mini Campus – Queen School Roads which have drainage system only on one side. These two road networks which total 1.72 km length shows that one sided drainage channel only represents 3.82% in the study area. However, Yebumot – Adeta Road had no drainage channel at all while Government House Roundabout - Challenge and Central Bank - Challenge Roundabout have sealed drainage system that could not be assessed.

Table 1. Characteristic of Micro Drainage in the Study Area
DC: Double Channel; ODC: Open Drainage Channel,
Source Author's Fieldwork (2015)

S/N		Nature of Road Network	Nature of Drainage Channel	Length of Road (M)	Length of Drainage Channel (Both Side) (M)	Depth at Construction (M)	Width of Channel (M)	Channel Capacity at Construction (M3)	Current Mean Depth (M)	Current Capacity (M3)	Reduction in Capacity (M3)	% Reduction in capacity
1.	Gaa Akanbi Roundabout – Danialu	DCL	ODC	1380	1380	1.00	1.00	1380.00	0.96	1324.80	55.20	04.00
2.	Garin Alimi – Dangote	DCL	ODC	1050	2100	0.61	0.61	781.41	0.29	371.49	409.92	52.45
3.	Garin Alimi – Sawmill	DCL	ODC	680	1360	0.61	0.61	506.05	0	0	506.05	100.00
4.	Garin Alimi – Yebumot	DCL	ODC	1200	2400	0.61	0.61	893.04	0.28	409.92	429.12	51.14
5.	Sawmill – Osere Junction	SCL	ODC	1140	2280	0.58	0.58	766.99	0.24	317.38	449.61	58.62
6.	Sawmill – Queen School	DCL	ODC	965	1930	0.61	0.61	718.15	0	0	718.15	100.00
7.	Queen School – New Market Junction	DCL	ODC	720	1440	0.58	0.61	509.47	0.37	325.01	184.46	3621
8.	Queen School – Owoniboys	DCL	ODC	875	1750	0.38	0.46	305.90	0.31	249.55	56.35	18.42
9.	Owoniboys – Unity Junction	DCL	ODC	560	1120	0.38	0.48	204.29	0.18	96.77	107.52	52.63
10.	Unity Road	DCL	ODC	580	1160	0.61	0.61	431.63	0.49	346.72	84.91	19.67
11.	Mini Campus – Queen School	SCL	ODC	340	340	0.61	0.61	126.51	0.27	55.99	70.52	55.74
12.	Unity Junction – Emirs Road Junction	DCL	ODC	880	1760	0.60	0.58	612.48	0.22	224.58	387.90	63.33
13.	Emirs Road	DCL	ODC	1,340	2680	0.89	0.89	2122.82	0.81	1758.34	364.48	17.16
14.	Opo Malu Road	DCL	ODC	875	1750	0.58	0.58	588.70	0.28	284.20	304.5	51.72
15.	Yebumot – Adeta Roundabout	SCL	NO DRAINAGE CHANNEL									
16.	Alfa Yahaya Road	SCL	ODC	840	1680	0.55	0.50	462.00	0.22	101.64	360.36	78.00
17.	Pataoloje – Ogidi Junction	SCL	ODC	550	1100	0.60	0.55	363.00	0.34	224.40	138.60	38.18
18.	Agbo-Oba Adeta Roundabout	SCL	ODC	1100	2200	0.75	0.60	990.00	0.62	818.40	171.60	17.33
19.	Oko Erin – Agbo-Oba Junction	SCL	ODC	340	680	0.55	0.58	216.92	0.21	82.82	134.10	61.82
20.	Oro Road	SCL	ODC	480	960	0.38	0.50	182.40	0.17	81.60	100.80	55.26
21.	Obbo Road	SCL	ODC	395	790	0.58	0.60	274.92	0.15	71.10	203.82	74.14
22.	Yoruba road	SCL	ODC	230	460	0.58	0.55	146.47	0.27	68.31	78.16	53.36
23.	Stadium Road	SCL	ODC	470	940	0.61	0.55	315.37	0.33	170.61	144.76	45.90
24.	Flower Garden – Tanke Junction	SCL	ODS	800	1600	0.53	0.70	593.60	0.47	526.40	67.20	11.32
25.	Tanke Junction – Tanke Roundabout	DCL	ODS	1,115	2230	0.61	0.58	788.97	0.49	633.77	155.20	19.67
26.	Tanke Roundabout – University Gate	DCL	ODS	1,220	2,440	0.60	0.66	966.24	0.47	756.89	209.35	21.67
27.	Awolowo Road	SCL	ODS	830	1,660	0.55	0.55	502.15	0.39	356.07	146.08	29.09
28.	Pipeline Road	SCL	ODS	1,425	2,850	0.61	0.62	1,077.87	0.28	187.11	890.75	82.62
29.	Gaa Akanbi Roundabout – Danialu	SLC	ODC	1,210	2,420	0.61	0.58	856.20	0.34	44.88	378.98	44.26
30.	Gaa Akanbi Roundabout – Equity Chambers	SLC	ODC	740	1,480	0.58	0.60	515.04	0.39	346.32	168.72	32.76
31.	Admiralty Villa Road	Double	ODC	1,235	2,470	0.61	0.58	873.89	0.55	787.93	85.96	09.84
32.	Flower Garden – Shoprite Road	SLC	ODC	700	1,400	0.63	0.60	529.20	0.53	445.20	84.00	15.87
33.	Fate Tanke Road	SLC	ODC	1,260	2,520	0.60	0.60	907.20	0.11	166.32	740.88	81.69
34.	Fate Roundabout – Niger Basin	SLC	ODC	750	1,500	0.61	0.60	540.00	0.38	342.00	198.00	36.67
35.	GSS Roundabout – Fate Roundabout	DCL	ODC	1,100	2,200	0.62	0.60	818.40	0.54	712.80	105.60	12.90
36.	Muritala Road	DCL	ODC	1,960	3,920	0.60	0.60	1,411.20	0.38	893.76	517.44	36.67
37.	Maraba Garage – GSS Roundabout	DCL	ODC	680	1,360	0.62	0.60	505.96	0.33	269.28	236.64	46.77
38.	Government House Roundabout – Challenge	SEALED DRAINAGE, INACCESSIBLE										
39.	Government House Roundabout – Fate	DCL	ODC	985	1,970	0.60	0.62	732.84	0.56	683.98	48.86	6.67
40.	Post office – Offa Garage	Double	ODC	2,050	4,100	0.65	0.61	1,625.65	0.48	1,200.48	425.17	26.15
41.	Adabata Road	Slane	ODC	1,250	2,500	0.60	0.60	900.00	0.34	510.00	390.00	43.33
42.	Ogidi	DCL	ODC	1,210	2,420	0.78	0.78	1,472.33	0.54	1,019.30	453.03	30.77
43.	Maraba – Pata Market	DCL	ODC	1,150	2,300	0.61	0.61	855.33	0.32	448.96	406.87	47.54
44.	Eruda Road	SLC	ODC	380	760	0.58	0.58	255.66	0.27	190.02	136.64	53.45
45.	Fossil Petrol Station – Unity Road	DCL	ODC	1,118	2,236	0.61	0.76	1036.60	0.52	883.66	152.94	14.75
46.	Cemetery Road	SLC	ODC	586	1,172	0.61	0.56	400.35	0.38	249.40	150.95	37.70
47.	GSS Roundabout to Sango	DCL	ODC	1,280	2,560	0.61	0.60	936.96	0.45	691.20	245.76	26.23
48.	Henrold – Post Office	SLC	ODC	920	1,840	0.60	0.58	640.32	0.33	352.52	288.14	45.00
49.	Matrite – Flower Garden	SLC	ODC	620	1,240	0.60	0.60	446.40	0.47	349.68	96.80	21.69
50.	Central Bank – Challenge Roundabout	SEALED DRAINAGE, INACCESSIBLE										
51.	Oloje Road	DCL	ODC	1,815	3,630	0.66	0.65	1769.63	0.48	1,306.80	462.20	26.12
52.	Atiku Road	SLC	ODC	925	1,850	0.60	0.60	643.80	0.45	499.50	144.30	22.41
53.	Erin-Ile Road	SLC	ODC	620	1,240	0.68	0.68	463.76	0.36	245.52	218.24	46.06
54.	Agba Dam Road	SLC	ODC	880	1,760	0.68	0.68	682.18	0.38	381.22	300.96	44.12
	TOTAL			45,044	84,922	31.09	31.09	36,646.71	18.99	23,267.40	13,379.31	36.51

The depth of drainage channel at construction in the study area range between 0.38 m observed in both Queen School - Owoniboys Road and Owoniboys - Unity Junction Road and 1.00 m observed in Airport-Garin Alimi Road. However, the current channel depth range between 0.11 m observed in Fate - Tanke Road and 0.96 m observed in Airport - Garin - Alimi Road. Infact, two road networks (Garin Alimi-Sawmill and Sawmill - Queen School) had zero depth as the channel networks along the two roads are completely filled up with sediments. While the mean channel depth at construction in the study area is 0.61 m, the current mean depth is 0.37 m. This value thus represents 39.3% reduction in mean channel depth between the period of construction and time of data collection for this study. Channel width in the study area has a mean value of 0.61 m and range between 0.46 m observed along Owoniboys - Unity Road Junction and 1.00 m observed along Airport - Garin Alimi Road.

The readings observed on both channel depth and width at construction in the study area are considered too low in this era of climate change, especially in a rapidly growing city like Ilorin situated in tropical environment. Studies such as Interagency Climate Change Adaptation Task Force (2011), Trenberth (2011), Intergovernmental Panel on Climate Change (2012), Gersonius et al., (2013) have indicated that increasing precipitation intensity and number of storm events are being experienced in different parts of the world induced by climate change. This fact will no doubt increase the magnitude of runoff discharge, and inundate the drainage channels. According to Denault, et al., (2012), one major assumption of the traditional approach in drainage infrastructure design is that the statistical parameters of the hydrological variables will remain constant over time without major fluctuations or long term trends. However, this assumption no longer holds as increase in radiatively active gases in the atmosphere is intensifying the hydrological cycle in different parts of the world. The implication of this is that, even with functioning drainage systems the capacity of such infrastructure will be unable to cope with the extreme rainfalls that are expected to be induced by climate change. Thus, as can be seen on figure 3, the small dimensions of drainage channels (both depth and width) which are designed for pre-climate change conditions in the study area are no longer able to accommodate the increasing runoff discharge.

Apart from the above described climate change induced problem of drainage infrastructure in the study area, urbanization process is also presenting a challenge. Ilorin, the study area is undergoing rapid urbanization process since it became a state capital in 1967. Oyegun (1987) observed the built-up area in the city to have grown from 20.40 sq. km in 1963 to about 58.00 sq km in 1982. By 1997, the area occupied by artificial paved surface in the city has increased to about 150 sq km with consequent effect on runoff generation. Urbanization process is one of the anthropogenic distortions to the theoretical operation of the hydrological cycle. According to Jones (1997), its greater consequence on catchment runoff pattern is as a result of paved surfaces. Increase in urban development usually results in reduced infiltration, increase in volume and rates of runoff discharge and reduction in lag time due to increase in velocity of overland flow (Hall, 1984; Roel, 1984). And with constricted nature of drainage system as observed in this investigation, the resultant effects are flooding, pollution, erosion, sedimentation amongst others. The total capacity of drainage networks at construction in the study area was 36,646.71 m^3 and a mean value of 718.56 m^3. However, the current total capacity of all the drainages is 23,267.40 m^3 and a mean value of 456.22 m^3. This thus shows that the total capacity of all the drainage networks in the study area has dropped by 13,019.31 m^3 which represent 35.53% reduction in carrying capacity. This reduction in carrying capacity is basically due to reduction in depths of the drainage channels caused mainly by anthropogenic activities. As a matter of fact, the percentage reduction in carrying capacity of two of the drainage networks examined in this study (i.e. Garin Alimi – Sawmill and Sawmill – Queen School) is 100%. This is because the two drainage networks have been completely filled up with sands and other waste materials. Three of the drainage networks (i.e. Airport – Garin Alimi, Government House Roundabout – Fate Roundabout and Admiralty Villa Road) however recorded very low (<10%) percentage reduction in carrying capacity. The tree drainage channels only recorded 0.4, 6.67 and 9.84% reduction in carrying capacity respectively; thus they can be regarded as being fairly clean of wastes and sand. The field result on these three drainages networks is understandable, Airport – Garin Alimi drainage channel is the deepest and widest in the study area. The drainage channel because of its dimensions of width and depth is thus able to transmit any load deposited into it easily as the competence is very high due to the amount of water it carries. The other two drainages are located in Government Reserved Areas where population density is very low. Not only that, much of the land area draining into the two drainages are covered by lawn, especially the Admiralty Villa Road drainage channel which drains runoff mainly from a Golf court.

Figure 3. Flood Situation in Ilorin

Figure 4. Solid Wastes in Drainage

As a result of urban growth accompanied by high population density, waste generation and disposal has become a serious environmental concern in the study area as can be seen on figure 4. It is this particular factor that can be largely held responsible for the high degree of sedimentation in the drainage channels examined. Generally, the nature of sediments found in the drainage channels in the study area can be categorized into eight; such includes plastics, polythene nylon, metals, glass, sand and stones, leaves, wood, and other miscellaneous materials such as cloths, food and animal remains. As can be seen on figure 5, the percentage composition of the sediments however vary significantly with sand and stones accounting for more than 65% while polythene nylon accounted for 11.71%.

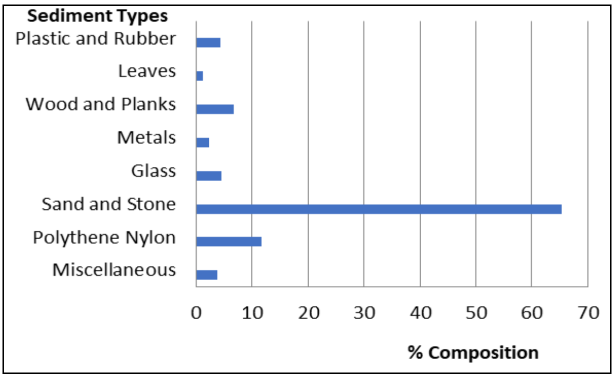

Figure 5. Percentage Composition of Sediments in the Drainage Channels
Source: Author's Fieldwork (2015)

The enumerated waste materials find their way into drainage channels due to peoples' poor attitude towards refuse disposal. It is even not uncommon to find people directly dumping their wastes into flowing water whenever it rains in the study area (Jimoh 1994; Iroye, 2008; Iroye, 2013). While lightweight materials such as plastic and rubber, leaves, polythene nylon, and wood thrown into micro drainages flow into the main rivers when runoff volumes are high, these materials stop moving when rain ceases, thus causing debris pile-ups which obstruct the movement of subsequent storm flow. The dumpling of heavy materials such as stones and metal debris into moving water reduces channels depth, affect drainage competence to carry load; hence the high sedimentation values observed in the studied channels. In some places, utility lines such as water pipes were found obstructing storm flow as they are laid across the drainage channels (figure 6) while in other places, the drainage channels have been overgrown by vegetation (figure 7). Both utility lines laid across drainage channel and vegetation growth within a channel serve as clog, preventing the free movement of solid wastes within drainage channel, thus encouraging sedimentation.

Figure 6. Storm Flow Obstruction by Utility Lines

Figure 7. Drainage Channel Overgrown by Vegetation

Effective and efficient drainage infrastructure is vital, especially in urbanized area such as Ilorin. Apart from the fact that it aids in flood control, it plays an essential role in public health and safety while also helping in the area of environmental protection. Poor drainage management aids the infiltration of polluted water into water supply systems such as broken pipes and shallow wells, it creates faecally contaminated wet soils while also serving as breeding sites for mosquitoes. Functional drainage infrastructure is thus effective and cheaper means of mosquito control; according to Cairncross and Quano (1991) it is cheaper than application of insecticides because it does not have to be repeated regularly. Not only that, drainage infrastructure has no detrimental effect on the environment like chemical insecticides; it rather constitute an environmental improvement. With good working drainage infrastructure, the danger of mosquito developing resistance to insecticide is completely removed.

CONCLUSION AND RECOMMENDATIONS

Effective and efficient drainage infrastructure is vital for flood control, reduction of pollution and promotion of public health and safety. However, in most cities of the world today, especially in developing countries, rapid urbanization process is combining with the incident of climate change to render most drainage infrastructure ineffective. While urbanization process increases the amount of runoff discharge due to reduction in infiltration capacity of the soil brought about by land pavement; climate change is producing an increase in both frequency and intensity of precipitation due to global warming. The event of climate change and the process of urbanization are thus combing to increase amount of runoff discharge which in most cities, inundate the drainage infrastructure.

This bad drainage condition which is mainly obtainable in developing countries is due to the fact that most drainage infrastructure in the region were design using traditional approach which was based on the assumption that the statistical parameters of hydrological variables will remain constant over time, without major fluctuations or long-term trends. However, recent climate change is rendering that assumption of stationarity erroneous as flooding induced by inundated drainages is now a common occurrence in most cities. Drainages designed for pre-climate change condition are neither deep nor wide enough to accommodate and transmit increased runoff discharge induced by climate change and urbanization process.

The poor waste generation and disposal attitude of the people is also exacerbating drainage problem as solid wastes dump into drainage channels clog the system, result in debris pile up and finally silt up the drainage channels. There is therefore the need to urgently revisit the traditional design practices, especially that of urban drainage in order to develop a more strategic approach which will incorporate not only the anticipated climate change impacts but will also factor in, the rapid rate of urbanization and peoples' poor waste generation and disposal attitudes. Specifically however, the study recommends that government and government agencies responsible should:

I. prioritize the implementation of drainage master plan in the study area;

II. involve citizens in drainage management by charging property owners drainage fees as part of property rate for maintenance;

III. develop a robust maintenance culture. This can be through: inspection of the entire drainage system at least once a year, visitation to problem sites during or immediately after heavy rainfall and removal of debris in the channels on a daily basis and;

IV. develop anti-dumping programme which can come inform of environmental education as earlier recommended by Jimoh and Ajibade (1995). This can be carried out through public enlightment programmes using various prints and electronic media. While the print media will help in re-educating the literate society, the use of electronic media such as radio and television programmes which can be carried out in different languages will help in educating the illiterate on the issue of environmental management.

REFERENCES

Aderamo, J. A. (1990). *Road development and urban expansion: The case of Ilorin*. Unpublished Ph. D Thesis, University of Ilorin, Nigeria, 10-25.

Aderogba, K., Oredipe, M., Oderinde, S., ...& Afelumo, T. (2012). Challenges of Poor Drainage Systems and Floods in Lagos Metropolis, Nigeria. *International Journal of Social Sciences & Education*, 2(3): 412-427.

Aid, A. (2006). Climate change, urban flooding and the rights of the urban poor in Africa. Key findings from six African cities. *A report by Action Aid International*.

Aina, T. A., Etta, F. E., ...& Obi, C. I. (1994). The search for sustainable urban development in metropolitan Lagos, Nigeria: prospects and problems. *Third World Planning Review*, 16(2), 201.

Ajibola, M. O., Adewale, B. A., & Ijasan, K. C. (2012). Effects of urbanisation on Lagos wetlands. *International Journal of Business and Social Science*, 3(17), 310-318.

Areola, O.O. (1978). Soil and Vegetal Resources. In: Oguntoyinbo, J.O, Areola, O.O. and Filani, M. (eds.) A. *Geography of Nigeria Development. Heinemann Books Ltd Ibadan.*

Cairncross, S., & Ouano, E.A.R. (1991). *Surface Water Drainage for Low Income Communities, WHO/UNEP Report Geneva Switzerland.*

Denault, C., Millar, R. G., & Lence, B. J. (2002). Climate change and drainage infrastructure capacity in an urban catchment. *Proceedings of Annual Conference of the Canadian Society for Civil Engineering* (pp. 5-6).

Department of Geography, University of Ilorin (1981). *Ilorin Atlas*, University Press 39 pp.

Dodman, D., Bicknell, J., & Satterthwaite, D. (2012). Adapting to Climate Change in Urban Areas: The Possibilities and Constraints in Low-and Middle-Income Nations: David Satterthwaite, Saleemul Huq, Hannah Reid, Mark Pelling and Patricia Romero Lankao. In Adapting Cities to Climate Change (pp. 25-69). *Routledge*.

Enendu, S. N. (1981). *Flood problems in Ilorin.* Unpublished B. Sc. dissertation, University of Ilorin, Ilorin, 68 pp.

Frimpong, A. (2013). Perennial Floods in the Accra Metropolis: Dissecting the Causes and Possible Solutions. *African Social Science Review*, 6(1): 1-4.

Gersonius, B., Ashley, R., Pathirana, A., & Zevenbergen, C. (2013). Climate change uncertainty: building flexibility into water and flood risk infrastructure. *Climatic Change*, 116(2), 411-423.

Goldenfum, J. A., Tassi, R., Meller, A., Allasia, D. G., & Da Silveira, A. L. (2007). Challenges for the sustainable urban stormwater management in developing countries: from basic education to technical and institutional issues. *NOVATECH 2007*.

Hall, M.J. (1984). *Urban Hydrology*, Elsevier Applied Science, Barking, U.K. 299 pp.

Herman, G. V. (2009). *Omul şi modificările antropice din Câmpia Someşului [The man and anthropogenic changes in Somes Plain]*, Editura Universităţii din Oradea, 227 pag., ISBN 978-973-759-981-0, Oradea.

Herman, G. V. (2010). Using Geographical Information (GIS) System for Management of Flood Risks in the Somes Plain, in *Cross-Border Partnership with Special Regard to the Hungarian - Romanian - Ukrainian Tripartite Border*, Book Editors Ioan Horga, Istvan Suli Zakar, Publishing House University of Debrecen Press, p. 175 -179.

Interagency Climate Change Adaptation Task Force (2011). *Federal Actions for a Climate Resilient Nation Progress Report Washington*, DC.

Intergovernmental Panel on Climate Change (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* In: Field, C. et al (eds.) A Special Report of WG I and II Cambridge University Press, Cambridge.

Iroye, K.A. (2008). *Effects of Landscape and Climatic Parameters on Basin Management in Ilorin, Kwara State Nigeria*.

Unpublished Ph.D Thesis University of Ilorin.
Jimoh, H. I. (2008). Drainage problems in a tropical environment: Perspectives on urban quality management. *Journal of Human Ecology*, 23(4): 325-329.
Jimoh, H. I., & Ajibade, L. T. (1995). Environmental education on soil erosion problems in Nigeria-An overview. Ilorion *Journal of Education*, 16: 39-45.
Jones, J. A. A. (1997). Inadvertent impact on hydrological processes 2: water quality. Global hydrology. *Processes, Resources and Environmental Management*, 242-276.
Mattingly, M. (1995). Urban management in less developed countries. University College, London, *Development Planning Unit*.
Miguez, M.G., & Rezende, O.M. (2012). Urban Drainage Trends: The Pathway Towards More Sustainable Solutions *Aqua-LAC* 4 (2): 69-83.
Olaniran, O.J. (1983). Flood Generating Mechanism in Ilorin, *Nigeria Geojournal*, 7 (3): 271-277.
Olaniran, O.J. (2002). Rainfall Anomalies in Nigeria: The Contemporary Understanding 55th Inaugural Lecture University of Ilorin 66pp.
Omole, D.O., & Isiorho, S. (2011). Waste Management and Water Quality Issues in Coastal States of Nigeria: The Ogun State Experience. *Journal of Sustainable Development in Africa,* 13 (6): 207-217.
Oyegun, R. O. (1983). Water Resources in Kwara State. *Matanmi and Sons printing and publishing Co. Ltd. Ilorin.*
Oyegun, R.O. (1987). Man-Induced Movement of Earth Materials into Ilorin City, Nigeria. *Environmental Education and Information*, 6 (2); 142-152.
Rahman, A. (2004). The State of Urban Drainage Conditions and Management in Aligarh City, India. *In: Proceedings of the 5th Novatech Conference on Innovative Technologies in Urban Storm Drainage* pp. 1303-1310.
Roels, J.M. (1984). Surface Runoff and Sediment Yield in the Ardche Rangeland. *Earth Processes and Landforms,* 9: 371-381.
Silveira, A. D. (2002). Problems of modern urban drainage in developing countries. *Water Science and Technology*, 45(7), 31-40.
Trenberth, K. E. (2011). Changes in precipitation with climate change. *Climate Research*, 47(1-2): 123-138.
Tucci, C.E.M. (2001) Urban Drainage Management in: Urban Drainage In: Tucci C.E.M (ed.) Humid Tropics. UNESCO International Hydrological Programme (I HP-V) *Technical Documents in Hydrology,* 40 (1): 157-176.
United Nations Centre for Human Settlements (1991). *Storm Water Drainage and Land Reclamation for Urban Development*. UN Habitat Publication.
Yilmaz, L. (2004). The Determination of Master Drainage Plans and the Reclamation of Storm water in Developing Countries In: *Proceedings of the 5th Novatech Conference on Innovative Technologies in Urban Storm Drainage* pp 1365-1368.

Submitted:	Revised:	Accepted and published online
August 02, 2018	Octomber 20, 2018	December 11, 2018