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ADAPTATION TO TEMPERATURE VARIABILITY AND DEGRADATION OF URBAN LANDSCAPE OF OWERRI MUNICIPALITY

[1]Nkwocha, Edmund E. & [2]Pat-Mbano, E. C.
[1]Dept. of Environmental Technology Federal University of Technology, Owerri Nigeria
[2]Dept. of Urban and Regional Planning, Imo State University Owerri Nigeria

ABSTRACT
The major impact of global warming is the increasing ambient temperature in most towns and cities especially in the developing world which has increased their level of vulnerability. The aim of this study was to investigate the effect of an adaptation strategy to temperature variability on the degradation of urban landscape of Owerri Municipality. Data were collected on temperature, humidity, heat index for a period between 1978 and 2010. A questionnaire survey containing pertinent questions bordering on sachet water consumption, time of consumption, reasons for consumption etc, was carried out on 522 subjects in Owerri. Results showed that during the 32 year period, the maximum mean temperature was 32.8^0C while the minimum mean temperature was 31.6^0C, showing a percentage increase of 3.7% while the mean average level of humidity progressively decreased from 6.4% between 1978 – 1987 to 4.7% between 1988 – 2010. The dramatic rise of Heat Index (7.2%) during the period created a situation of hot weather conditions which led to high consumption of sachet water which served as a coping strategy by local population. Unfortunately, this has led to the generation and littering of large quantities of sachet water plastic wastes that has ultimately caused the degradation of Owerri urban landscape. The case of Owerri provides a strong evidence not only on the relationship between temperature variability and environmental degradation, but also the low level of coping capability of towns in developing countries in facing the consequences of temperature variability due to climate change.

KEYWORDS: Adaptation strategy, Heat index, littering, sachet water, temperature variability, urban degradation

INTRODUCTION

In recent times, there have been serious efforts by scientists in different parts of the world to analyze or even predict the general effects of global warming and climate change on environment (Trewin and Vermont 2010; Meehl et al 2009 and Trenberth et al, 2007). Growing concerns about global temperature increase have led to increasing research attention on related topical issues. A handful of researchers have demonstrated the impact of global warming and climate change on human health (McMichael 2006; Epstein 2005; Burns 2002) and on water resources, wetlands and fresh water ecology (Okpokwesili *et al* 2004). Global warming has also been associated with elevated heat and heat-waves (Rudnick, 2002, Chestnut *et al* 1998), rapid dehydration during dry season (Michel and Turner 2006, Mill 2005) and exacerbation of desertification process (IPCC2001). The extent to which temperature increase and weather patterns shift and the potential consequences for human health in relation to the spread of vector-borne diseases have been discussed by a retinue of authors (Gamble *et al* 2008; Phillips 2008; Dhar 2008). There are also reports that global warming may significantly alter soil composition at the molecular level (Frazer 2009) drastically affecting agricultural land resources and biodiversity (Hartfield 2008), thus causing flooding in most of the worlds' coastal cities (Holzman 2008). These studies were based on the growing evidence of increased rate of CO2 emissions into the atmosphere which may have jumped from 1.3 percent to 3.3 percent per year from 1990s to 2000-2006 possibly as a result of declining global sinks and increased economic activities (NRC 2008, Canadell *et al* 2007). However, despite these research efforts on the general effects of global warming and climate change, their actual and future effects on urban environmental systems especially in developing countries have received cursory attention. In the last few years, Nigerian towns and cities have been experiencing a lot of events directly or indirectly related to global warming (Adefolalu 2007, Ikhile 2007, Obioh 2002), and have become harbingers of climate change (Ziska et al 2003). There have been reported cases of coastal flooding from Atlantic Ocean in Lagos that displaced many local residents causing loss of lives and property. In the early part of 2011 more than one hundred lives were lost at Ibadan, Oyo State due to flooding resulting from torrential rains. However the major direct impact of global warming is the increasing ambient temperatures in most towns and cities which increased their level of vulnerability and compounded their coping strategies to climate change (Odjugo 2010, Okali and Eleri 2004). Vulnerability in this context is the extent to which temperature increase may create highly sensitive to modest changes and which the ability to adapt is severely constrained, while adaptation is the ability to adjust to prevailing conditions; having the potential to reduce adverse impacts in order to reduce vulnerability (Sheridan and Dolney 2003). This paper discusses additional dimension of environmental change associated with global warming and climate change. It tries to investigate to what extent an adaptation strategy by local

population in a Nigerian town to temperature variability contributes to the degradation of its urban landscape.

MATERIALS AND METHODS

Study Area

Owerri is the regional capital of Imo State in the South-East Nigeria. With a landmass of 24.88km^2, it lies between latitude 5.29'N and longitude 07^0 02' E. The topography is made up of gently sloping low lands that facilitated rapid urbanization and growth of human activities. It has an estimated population of about 145,000 based on the 2006 National Population Census (NBS, 2007). Due to absence of established industries and the prevailing economic hardship in the country, many of its residents are either public servants or are engaged in the activities of the informal sector (traders, hawkers, tradesmen, artisans, etc.) which are practiced in the open air that expose them directly to weather conditions. In Owerri, there is persistent problem of potable water supply since the end of 1980s due to population increase resulting essentially from rural migration. However, in recent times, there has been perceived temperature increase and excessive heat conditions in many towns in Nigeria including Owerri. One of the coping strategies to face this situation is the massive production and consumption of *sachet water* (locally called "pure-water") which originated in Lagos in the early 1980s and later spread across the country. It is water of about 5cl contained in a transparent plastic pack electronically heated and sealed at both ends. The sachet-water is potable, affordable (N5.00 per sachet), usually served chilled and made available to the public by numerous street hawkers made up of mainly women and children. The number of factories producing different brands of sachet water has increased in recent times, numbering more than 350 in Nigeria and 18 in Owerri. People now consume sachet water as an adaptation strategy to cope with increasing daily temperatures and excessive heat conditions especially during the dry and harmattan seasons. The consumption of sachet water generates a lot of plastic waste in the area.

Data Collection

Data used for this study were obtained from different sources. Data on temperature and humidity were acquired from Nigerian Meteorological Monitoring Station Owerri for the period between 1978 and 2010. Maximum temperature for each day was read at 1500 UTC (4pm local time), and properly documented since long time variations in average temperatures are single most important attributes of climate change (Masters 2006). Data validation, screening and averaging (i.e. daily, quarterly, annually and decadal) were performed before they were used for analysis in this study. The screening and validation followed the procedure described by Davis *et al* (2003a). Data obtained on temperature and relative humidity enabled the calculation of the heat index (apparent temperature) following the methods adopted by NWS (2005) and Ebi *et al* (2004). The temperature-heat index was calculated for the period to reflect overall temperature discomfort (how hot it feels) accounting for temperature and humidity (Kalkstein and Valimont 1986). The value of the index is high when high air temperatures occur and low when they occur at low humidity (Kalkstein 2002). The second source of data was through a questionnaire survey on residents in Owerri who directly experience the effects of temperature variability. Data was collected through the use of a structured questionnaire that contained multiple answers in which copies were directly administered to respondents in different districts of Owerri. They were interviewed in English or in local vernacular (Igbo) within a period of four weeks. The questionnaire contained pertinent questions bothering on age, sex, level of education, why they consumed sachet water, quantity consumed per day, time of consumption and how they handled the sachet-water waste generated after consumption. Subjects were selected through a systematic random sampling in which members of households in one out of every three buildings along major streets and roads were surveyed using street numbers. Education and status of subjects was assumed to affect their sachet water consumption and littering habits. Therefore, if a subject accepted to have consumed sachet water, the next question aside those earlier mentioned, was to know his/her personal details (age, sex, etc). Education levels attained by respondents were classified as primary, secondary and tertiary. In the same vane, occupation was classified as formal (public servants, private institutions etc) and informal (not registered with government). Informal activities included artisans, mobile traders, hawkers, shop owners, food sellers and all those practicing their trade along major streets and roads. The quantity of sachet water consumption were indicated as "low", "average", "high" and "very high". This approach helped to collect data on issues relating to sachet water consumption and degradation of urban landscape due to littering of sachet water waste. A total of 522 subjects were interviewed.

Data analysis

Data collected were analyzed using unvariate and multivariate models. At first level, data on temperature, humidity and heat index were subjected to time-series analysis to determine decadal evolution of records in means and percentages.

The descriptive statistics for sample characteristics of sachet water consumption, reason for, and time of consumption, and how subjects handled their wastes after consumption were calculated. The bivariate correlations of variables of interest were tested based on estimated Spearman Correlation Coefficient and used paired t-tests to examine the level of significance or otherwise of the relationships between these variables. Multiple linear and logistic models were used to determine whether temperature and heat index influence water consumption, after adjusting for potential confounding factors. Control variables for analysis of water consumption and the resultant sachet water waste generation included age, sex, level of education, occupation and time. A p-value of $p<0.05$ was considered to be statistically significant. All statistical analyses were completed using the software package SAS Version 9.1 (SAS Institute Inc. Cary, NC, USA).

RESULTS

Time-series analyses of temperature records showed that between 1978 and 1987 the minimum mean temperature was 31.4 ^{0}C while the maximum mean temperature was

32.7^{0}C; between 1988 and 1997 the minimum mean temperature was 31.6^{0}C and the maximum mean temperature was 32.8^{0}C and finally, between 1998 and 2007 the minimum mean temperature was 31.9^{0}C while the maximum mean temperature was 33.1^{0}C. The decadal percentage increase of the maximum mean temperatures with references to the maximum mean temperature recorded in the base year (1978) were 3.2%, (1978-1987), 3.5% (1988- 1997) and 4.4% (1998-2007) respectively as shown in Table I.

TABLE 1: Decadal Evolution of Temperature, Relative Humidity and Heat Index Between 1978 and 2007 (Mean values)

Years (Decades)	Maxi. Relative Humidity	Minimum Relative Humidity	% increase of Relative Humidity	Maxi. Temp. (^{0}C)	Mani. Temp. (^{0}C)	% increase in Temp	Maxi. Heat Index	Mani. Heat Index	% increase in Heat Index
1978 - 1987	67.09	61.58	6.4	32.7	31.4	3.2	39	37	5.4
1988 - 1997	65.5	60.8	3.9	32.8	31.6	3.5	40	37	8.1
1998 - 2007	66.0	61.2	4.7	33.1	31.9	4.4	36	36	8.1

Temperature exceedances calculated as a deviation or anomaly from a fixed reference annual mean value of 32.2^{0}C from 1983 to 2010 showed an interesting evolution. While there was an increase in temperature anomaly between 1983 and 1987 to the tune of 0.5^{0}C, the value sharply increased from 0.1^{0}C in 1997 to 0.9^{0}C in 1998 and later fell to 0^{0}C in 2000, then rose to a high value of 0.8^{0}C in 2007 and 1.0 in 2010 as shown in Fig. 1 & 2.

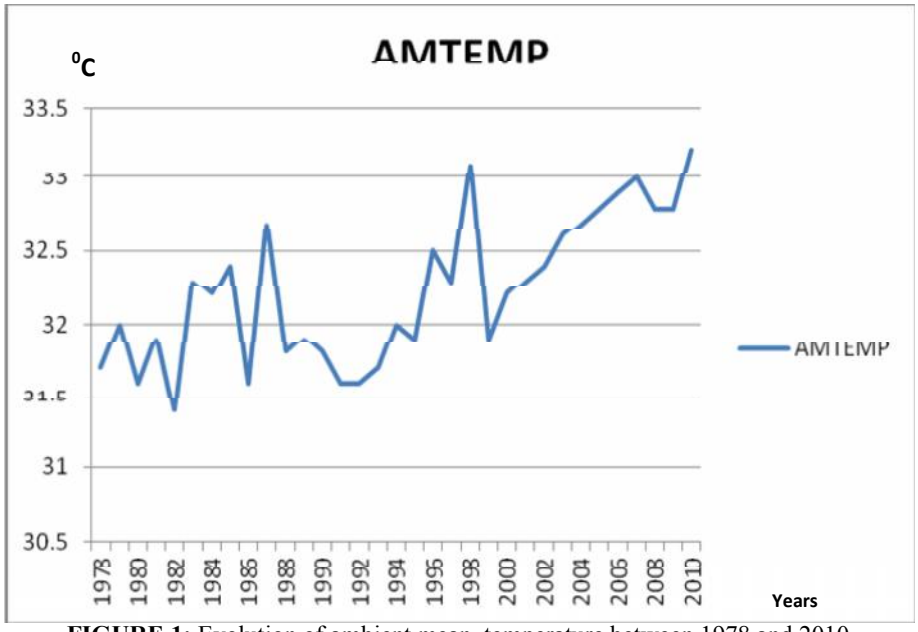

FIGURE 1: Evolution of ambient mean temperature between 1978 and 2010

The highest temperature exceedance was therefore recorded in 2010 followed by 1998 and 2007 respectively.

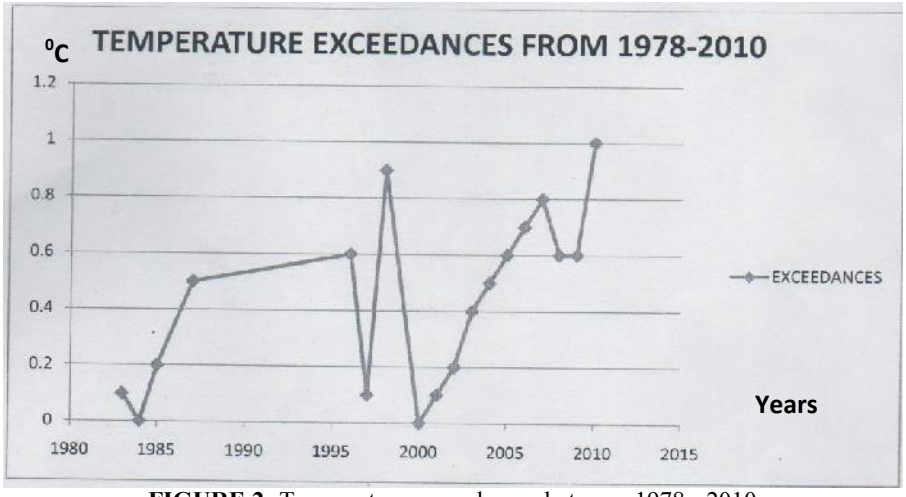

FIGURE 2: Temperature exceedances between 1978 - 2010

The mean relative humidity (MRH) observed at 1500Z between 1978 and 1987 recorded a maximum value of 67.09%, while the minimum value was 61.58%; between 1988 and 1997 we recorded a maximum value of 65.5% while the minimum value was 60.8%; and between 1998 and 2010 it was 66% for maximum value and 61.25% for minimum value as indicated in Fig 3

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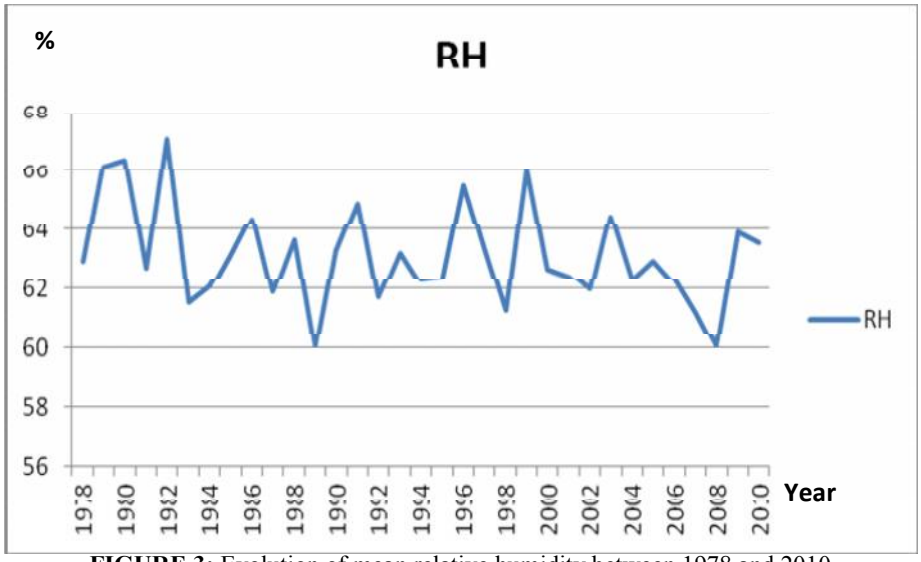

FIGURE 3: Evolution of mean relative humidity between 1978 and 2010

The percentage increase between the maximum mean values for the three decades, with reference to the maximum mean value for the base year were 6.4% (1978-1987), 3.9% (1988-1997) and 4.7% (1998-2010) respectively. Similarly, the evolution of heat index indicated a maximum mean value of 39^{0}C and a minimum mean value of 37^{0}C between 1978 and 1987; a maximum mean value of 40^{0}C and a minimum mean value of 37^{0}C between 1988 and 1997; and finally a maximum mean value of 40^{0}C and a minimum mean value of 30^{0}C between 1998 and 2010. The decadal percentage increases for HI were 5.4% (1978-1987), 8.1% (1988-1997) and 8.1% (1998-2007) respectively as clearly shown in Fig 4.

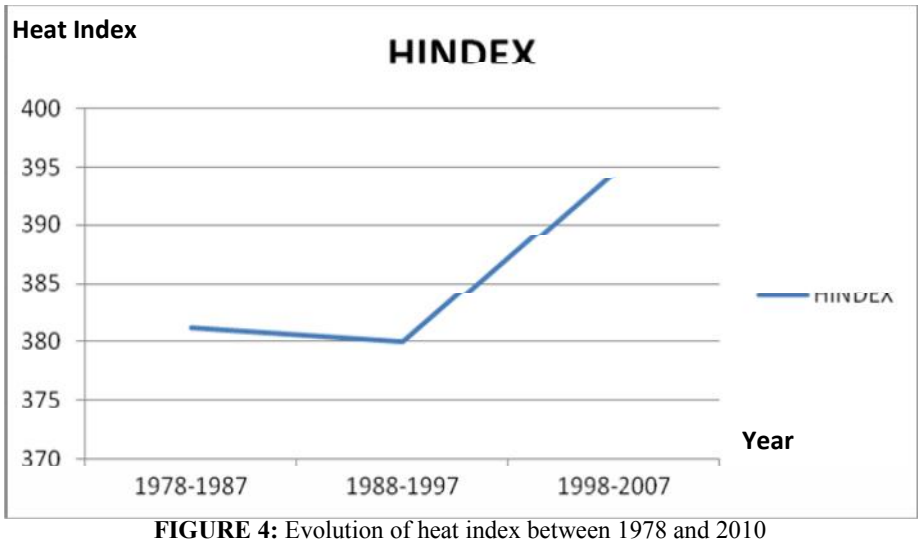

FIGURE 4: Evolution of heat index between 1978 and 2010

Relationship between ambient temperature and relative humidity was -0.41 signifying a significant relationship. However, the negative coefficient indicated an inverse relationship between the two variables, meaning that as temperature increases, relative humidity decreases which is in line with a priori expectation.

A strong and direct relationship of 0.69 was observed between temperature and water consumption; as temperature rises, the level of water consumption equally rises. Finally, a strong relationship of 0.64 was equally observed between HI and water consumption as shown in Table 2.

TABLE 2: Summary of Correlation between the Variables

	AMTEMP	RH	WC
RH	-0.41		-0.410
	0.018		0.018
WC	0.697	-0.292	
	0.000	0.100	
HINDEX	0.803	0.025	0.641
	0.000	0.892	0.000
Cell contents	Pearson	Correlation	p-value

RH = Relative Humidity AMTEMP = Ambient Temperature
WC = Water consumption HINDEX= Heat Index

However, in terms of water consumption association varied according to the subsets of the subjects based on age. It was strongest for subsets between the ages of 21 and 35 (OR=3.1, 95%, CI 1.3 -7.5) than those below 21years (OR=2.5, 95%, CI 1.7-7.5) and those above 45years (OR=2.3, 95%, 1.5-5.3). Correlation during the two seasons (dry and rainy seasons) were 0.71 and 0.63 for temperature, 0.59 and 0.33 for RH, 0.77 and 0.61 for HI and 0.81 and 0.74 for sachet water consumption. There was a strong association between temperature, RH, HI and sachet water consumption in the overall data set (OR=3.5, 95%, CI 1.3-5.9).

The socioeconomic characteristics of respondents are shown in Table 3. On why they consumed sachet water, all respondents (100%) related it with their exposure to increasing daily ambient temperature especially between 11am and 5pm which increased their body temperature and increased transpiration. Consequently, each respondent consumed an average of 3 sachet water per day, even though the average daily quantity consumed varied among them. Consumption was observed to be very high among subjects of the informal sector exposed to direct sunlight (hawkers, brick-layers artisan, auto-mechanics, etc) who consumed more than four packs a day. Subjects of the formal sector (teachers, public servants etc) who are less exposed to sun-light, consumed at least 3 sachets per day.

TABLE 3: Socioeconomic Characteristics of Subjects (n= 522)

Age (years)	**No/%**
<20	70 (13.4)
21- 35	163 (31.3)
36-46	157 (30.1)
47 - 65	80 (15.3)
>66	52 (9.9)
Sex	**No/%**
Male	268 (51.34)
Female	254 (48.**66)**
Income level (₦)	**No /%**
<5000	168 (32.2)
5000 - 15,000	152 (29.1)
15000 - 30,000	88 (16.9)
30,000 - 60,000	72 (13.8)
>60,000	42 (8.0)
Education level	**No/%**
Higher education	138 (26.4)
Average education	183 (35.1)
Lower education	201 (38.5)

Consumption varied among sex and age. The male folk, especially those between the ages of 21 and 35 years recorded the highest consumption level (4 sachets per day) followed by those between the ages of 36 and 46 years (3 sachets per day). The female folk between the ages of 21 and 35 years recorded the highest consumption levels (3 sachets per day) followed by those between the ages of 36 and 46 years (2 sachets par day). The least consumption levels were recorded among subjects above 66 years of both sexes and those below 20years of age (2 sachets per day). Subjects also responded to the question on how they handled their sachet water waste. The greater majority of them (92%) indicated that they littered it along the streets because of absence of waste bins. However, 73% indicated they threw their waste 'anyhow' which shows their level of ignorance, having no knowledge of the health and aesthetic implications of their actions. Also, 65% of subjects littered their sachet water waste along the streets for lack of legislation, as neither penalties nor punishment were meted out against those who littered these packs. Only 3% of subjects failed to give answers as to how they handled their sachet water waste. Educational levels of respondents did not affect their littering habits as they littered their sachet water irrespective of their level of education. Available records on sachet water consumption in Owerri between 1995 and 2010 were estimated at 3,683,620 packs generating same quantity of sachet water wastes in the town.

DISCUSSION

Two major observations were made concerning the evolution of temperature records during the period under review. Firstly, the recorded total mean temperature was 32.8^0C while minimum mean temperature was 31.6^0C showing a general percentage increase of 3.7%. Maximum mean temperatures showed a progressive increase over the three decades passing from 37.7^0C between 1978 and 1987 to 32.8^0C between 1988 and 1997 and ultimately to 33.1^0C between 1998 and 2010. These warming trend showed more records on high daily maximum temperatures (hot extremes) than those on minimum temperatures (cold extremes) which therefore corroborate different research results obtained both at regional levels (Agular *et al* 2009, Hulme *et al* 2001) and at global level (IPCC 2007). However, the warmest years on record in this town were 2010 followed by 1998 as opposed to the warmest global temperature recorded in 1995 as reported by Masters (2006). Also, during the 32-year period the maximum

mean heat index was 38.3^0C while the minimum mean value was 36.8^0C showing an increase of 7.2%. These values indicate a dramatic rise in heat index within the town, a situation which has plunged the local population into experiencing extreme weather conditions (Ayoade 2003, Odjugo 2010). Temperature and HI records in the area during the period between 1985 and 2010, particularly between 1995 and 2000 indicated notable increase and tremendous deviations from typical conditions, observations and trends which correspond with general observations by IPCC (2007) on the one hand, and BROWN *et al* (2008) and King et al (2000) on the other hand.

At Owerri, the consumption of the readily available and cheap sachet water is only a coping strategy by the local population to face these increasing temperatures. It is a means of regulating internal body temperature in order to overcome the effect of dehydration and heat exhaustion experienced by people through heavy sweating and dizziness. Without enough water consumption, perspiration will be inadequate or even cease and body temperature will rise (Tibbetts 2007, USEPA 2006), but maintaining a consistent body temperature (generally 98.60 F) is essential to normal physical functioning (American Medical Association Council in Scientific Affairs, 1997). In this case, 82% of respondents complained about experiencing high body temperature during the day, 80% complained about sweating profusely (especially those engaged in vigorous outdoor activities) while 53% complained about occasional headache and dizziness especially during the day. These are some of the condition associated with excessive heat events resulting from exposure to high daily temperatures (Brown et al 2008, Kunihiro and Foster 2004, NWS 2004). However, this spontaneous response of sachet water consumption to adapt to increasing daily temperatures had lead to the volumetric increase in the generation of plastic waste. These plastic sachets are disposed of indiscriminating along major roads, motor parks, public places, schools, offices, streets, gutters and at any available space in the town. The "throw-away mentality" among residents in Owerri is growing with reckless concern. Recent studies have shown that 61% of littered objects in the town are made up of these colourless polyethylene products resulting from sachet water consumption (Nkwocha and Ekeoma 2009). This situation has ultimately led to the degradation of the entire landscape of Owerri town. At present, there are no existing structures (waste bins, laws, etc) to accommodate the increasing generation of sachet water waste and to mitigate the littering habits of urban residents. Littering of these wastes has become so pervasive that its level of nuisance has become a major concern to authorities of the municipality. The growing danger of this menace in the area is that littering of these wastes cuts across different ages, educational levels and occupations, because almost everybody, including teachers, doctors, lawyers, hawkers, artisans, students are caught by this "throwaway web". While it is easier for urban waste collectors to remove the normal municipal wastes generated by the local population using the traditional door –to –door and communal methods of collection, it has become more and more difficult for them to collect these sachet water wastes due to their ubiquitous nature. If individuals become aware that consuming sachet water is only a coping strategy to face the increasing daily temperatures and that they require to dispose of these plastic wastes at the waste collection centres scattered throughout the town, adaptation to temperature variability by the local population may be faster and environmentally friendly. But the contrary is the case. Consequently, Owerri which used to be a reference town in the 1980s in terms of urban cleanliness has gradually degenerated into a dirty and unsightly town with all its neighborhoods and districts affected by this menace. The promptness of this adaptation strategy to cope with the unusual excessive heat conditions and the resultant sachet water wastes with no existing structures to manage it, at least in the short term, shows the level of unpreparedness of the local population in Owerri in facing the consequences of temperature increase due climate change. The case of Owerri therefore is another piece of evidence that corroborates the stance of many researchers that the effect of climate change will be felt more by developing countries especially those in Africa due to their low level of coping capabilities (Mshelia 2005, Nwafor 2007).

CONCLUSION

This study has tried to investigate how adaptation strategy to cope with increasing urban temperature has led to the degradation of Owerri urban landscape. The case of Owerri has demonstrated that temperature variability resulting from global warming is a reality. The results from this study are consistent with the hypothesis that populations in the most vulnerable areas of the world, especially Africa, will find it difficult to acclimatize to elevated temperatures. The consumption of sachet water is a spontaneous adaptation of the local population of Owerri in coping with excessive heat conditions resulting from temperature variability. Unfortunately, this ingenuity displayed by the local population is not matched with the provision of structures to accommodate the emerging plastic waste from sachet water consumption and has resulted in the degradation of urban landscape due to the littering of these wastes in different parts of the town. The adaptive response, despite serving its purpose to a large extent, is considered not to be environmentally friendly, at least in the short-term. This clearly shows the low level of preparedness of local population of Owerri in facing the consequences of temperature variability and climate change. There is need for the local authorities to embark on public education and sensitization on the problem of global warming and climate change as well as the danger of littering sachet water wastes and all wastes along the streets. The sensitization of young people on the ways of civic behavior and wrong waste disposal habits has become imminent in the area. Anti-litter posters should be displayed at strategic places to the attention of most street users, persuading them to "bin" their plastic wastes with much civility. Enough waste bins should equally be provided along the streets and major roads at recommended distances for people to 'bin" their sachet water waste and other wastes. Lastly, the formulation and enforcement of appropriate environmental laws, which should be punitive as well as serve as deterrent to future

litterers is very important. This will help in making the littering of all types of wastes an environmental crime and perpetrators as persons whose acts are anti-social and punishable. The case of Owerri is not unique to this problem, as most towns in Nigeria experience the same phenomenon. A general study on temperature variability and environmental degradation at national level will be particularly useful as this will help to expose associated trends and events and particularly expose the most vulnerable areas so as to evolve environmentally friendly strategies to cope with increasing urban temperatures and climate change in the years ahead.

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