IMPLICATIONS OF CLIMATE CHANGE ON HUMAN COMFORT IN BUILDINGS: EVIDENCE FROM NKONTOMPO COMMUNITY OF SEKONDI-TAKORADI, GHANA

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ABSTRACT

Climate Change has become the most talked about issue in recent times. The impact of climate change is likely to become more evident in the coming decades. Currently, atmospheric conditions, especially in the dry season, are getting hotter and drier with increased heat waves. Increased demand for air-conditioning for space cooling as a result of internal discomfort in buildings is already manifesting. This could put an additional stress on the already over-burdened energy capacity of the nation. The study on implications of climate change on human comfort in buildings was conducted in Nkontompo community, a suburb of Sekondi-Takoradi Metropolitan area of the Shama-Ahanta District of the Western Region of Ghana. The objectives of this study are to assemble and disseminate information about some of the possible impacts of climate change on the built environment. This is to set the platform for building professionals to identify possible adaptive measures to serve as basis for development of standards to maintain and enhance the quality of life in buildings. The results showed that there were significant changes in temperature, precipitation, and relative humidity. A rise in temperature and humidity levels constitutes a potential hazard to health and human comfort and accelerates many degradation processes and material damage. Subsequently, the amount of energy needed to maintain the condition of air in spaces at comfort levels keep increasing. It is therefore imperative that landlords and other property owners should be effectively guided by qualified professionals within the framework of policy guidelines based on sound research.

Keywords: **Climate Change, Greenhouse-effect, Comfort zone**

INTRODUCTION

In addition to the more stringent budget and efficiency requirements, the construction industry will have to adapt to climate change in the coming years. Virtually all existing buildings were designed and built partly based on building standards formulated with historical climate conditions. They were built many years ago and are expected to be standing many years to come. In the same sense new buildings that are yet to be designed and constructed will have to be operational for a long period of time during which the climate is expected to change.

Studies made by the Inter-governmental Panel on Climate Change (IPCC) reveal that the global climate condition is changing (Houghton et al, 2001). It adds that the conditions are however expected to get severe in the coming decades with seasonal changes coupled with extreme climatic events. Very hot days would be experienced. Dry seasons are expected to become hotter and drier.

Research has proven that the concentrations of certain "heat-trapping" gases in the atmosphere, popularly known as the greenhouse gases (GHG), are on the rise (Oberthür et al., 1999). The emission of GHG, mainly carbon dioxide (CO_2), into the atmosphere results in greenhouse effect. Natural greenhouse effect increases the global atmospheric temperature to about 15 degrees celsius, a temperature warm enough to sustain life on earth (Oberthür et al., 1999). However, human activities, such as burning of fossil fuels in industrial activities, electricity generation and transportation release more CO_2 and other greenhouse gases into the atmosphere. Gradual accumulation of such gases causes a rise in atmospheric temperature, and eventually a rise in the global surface temperature. By so doing the basic mechanism of natural greenhouse effect is altered and leads to additional induced greenhouse effect. This phenomenon of human induced greenhouse effect is popularly known as "global warming". However, in international discussions the term "climate change" has been used to cover greenhouse effect and all its varied impacts (Oberthür et al., 1999).

There has been a lot of effort by the United Nations Framework Convention on Climate Change (UNFCCC) towards reducing the emissions of greenhouse GHG into the atmosphere. However, there are concentrations of greenhouse gases already emitted into the atmosphere. For instance, carbon dioxide, which is the main GHG, has an effective lifespan of around 100 years in the atmosphere (EPSRC, 2003). That means even if GHG emissions into the atmosphere were reduced it would take decades for any atmospheric concentrations to reduce. This implies that the effects of climate change would continue to develop.

The impact of climate change is likely to become more evident in the coming decades. Buildings, generally, are designed and constructed for use over a long period of time. People are living in and will continue living in buildings designed on the basis of past climates rather than the warmer conditions experienced today and the more extreme climates that are expected in the future as a result of climate change.

This informs building professional and policy makers that provision for future condition is essential in present day building design, if not it could pose severe consequences. Resilience of existing buildings would also have to be improved. Currently, atmospheric conditions, especially in the dry season, are getting hotter and drier with increased heat waves. There has been an increased demand of air-conditioning for space cooling as a result of internal discomfort of buildings. Non-physical effects such as increased energy demand for space cooling by air-conditioning, mostly in hotels and administrative buildings, are already manifesting. This could put an additional stress on the already over-burdened energy capacity of Ghana.

The Concept of Thermal Comfort Condition in Buildings

The optimum thermal comfort condition in buildings can be defined as the situation in which the least extra effort is required to maintain the human body's thermal balance (Gut *et. al.*, 1993). The greater the effort that is required the less comfortable the climatic condition. In normal design practice maximum comfort condition can usually not be achieved. However, the designer's aim will be to design a house and have it built to provide an indoor climate close to the optimum. This is a range in which thermal comfort is experienced. This range is called the human comfort zone (Szokolay, 1981). The comfort condition differs with individuals within the range. It depends also on the clothing worn, the physical activity, age and health condition. Although ethnic differences are not of importance, the geographical location plays a role because of living habits and the acclimatization capacity of individuals. Four main factors, besides many psychological and physiological factors, determine the comfort zone. These are air temperature, temperature of the surrounding surfaces (radiant heat), relative humidity and air velocity (Gut *et al.*, 1993).

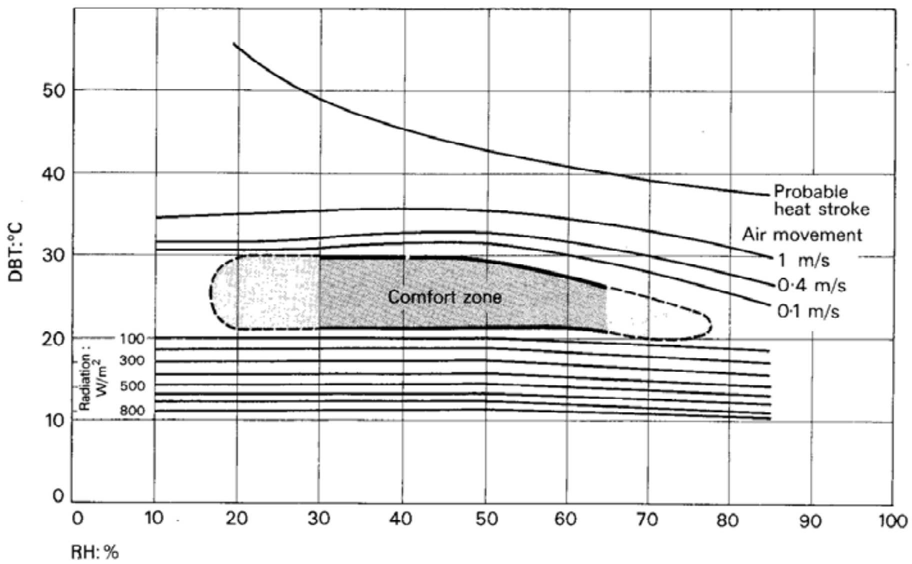
The relation of the four factors that determine the comfort zone is illustrated on the Bioclimatic chart, which was developed by Olgyay (Szokolay, 1981). It provides a method of establishing an environmental comfort condition through the interaction of the four climatic variables on the bioclimatic chart. The chart has relative Humidity as the abscissa and temperature as the ordinate as indicated in Figure 1. The comfort range is plotted on the chart. The chart indicates the zone where comfort is felt in moderate climate zones, wearing indoor clothing and doing light work.

A comfort zone is first defined in terms of dry bulb temperature and relative humidity, with the assumption that the air is still and there is no radiant heat gain or loss.

Monthly hourly diurnal "loops" of temperature and humidity conditions for each month, in any given location, can be plotted on the chart. This provides a "diagnosis" of the extension of underheated, comfortable, and overheated conditions in that place (Szokolay, 1981).

In the overheated situation the chart specifies the air speed of evaporation rate that may restore comfort. This can be achieved through cooling and dehumidification by an airconditioner and/or a dehumidifier. This scenario applies in the hot climates. Situation of the underheated range applies in the temperate regions or environments.

Figure 1: The Bioclimatic Chart



Source: Koenigsberger,1974, Pg.51)

APPROACH TO DATA COLLECTION AND ANALYSIS

A wide range of data were collected in order to get the required information. In order to find out the current issues related to the subject matter, a number of literature were reviewed. Primary data were obtained through interviews with the local residents of the study area. The interviews focused on their awareness of impacts of climate change, and their activities on adaptation and mitigation were assessed. The research covered events of the past 20 to 30 years.

Interview sessions were held with key informants; experts, scientists, personnel working in the field of development and having knowledge on the subject of investigation. The interview focused on the local people's awareness of impacts of climate change, and their responses to the impacts and the institutional capacity available for adaptation and mitigation. Some of the institutions where experts were interviewed are the Building and Road Research Institute (BRRI), Environmental Protection Agency, Engineering and Architectural Consulting firms, Technical Experts of the Architectural and Engineering Services Limited (AESL) and The Ministry of Water Resources, Works and Housing, the Departments of Civil Engineering and Architecture of Kwame Nkrumah University of Science and Technology (KNUST).

Daily values of rainfall amount, maximum and minimum temperatures, and relative humidity of Nkontompo in the Sekondi-Takoradi area, were obtained from the Meteorological Services Department of Ghana (MSDG) in Accra. It covered a thirty-year period from 1971 to 2000. A thirty-year period is recommended by the World Meteorological Service for an appreciable variation in climatic conditions (Feenstra et. al., 1998).

The climatic data (temperature, precipitation and relative humidity) of the study area were analysed to determine their trends for the last three decades. Microsoft Excel was used for data analysis and graphical presentations. The trends of temperature, precipitation and relative humidity were calculated as a slope of linear-trend line of the observed values. Decadal mean values for temperature and relative humidity were computed from the climatic data for the thirty-year period and plotted on the Bio-climatic Chart.

PROFILE OF NKONTOMPO

The Nkontompo community is a suburb of Sekondi-Takoradi Metropolis and one of the numerous settlements along the coastline of the Shama-Ahanta East District. The district is one of the eleven administrative districts of the Western Region of Ghana. Nkontompo is predominantly a fishing community, with a section of the working population involved in petty trading. The district falls within longitudes 1° 35’’W and 1° 49’’W and latitudes 4° 52’’N and 5° 08’’N, and is located about 245km to the west of Accra. It shares common borders with Shama-Ahanta West district to the southwest, Mpohor Wassa East district to the northwest and north, and the Gulf Guinea to the south.

Thermal Behaviour of Buildings in Nkontompo

The community occupies an elevated coastal plain which covers a land area of approximately 27acres, with about 915 buildings. The basic building form is rectangular or square form. Walls are either constructed of sandcrete or landcrete blocks with the former forming about 62% of the total. The walls generally have a cement-sand mortar finish (Fig. 2a). The high income landlords in the community add a touch to the walls by painting them. However some of the buildings do not have any finish.

This condition exposes the blocks to so much moisture that influences the thermal condition in the internal space.

Fig. 2a: Landcrete wall with cement-sand mortar finish

Fig. 2b: Rafter-purlin-aluminium sheet roofing system with no ceiling

The design of the roofing system as well as the materials used is varied throughout the community. However, hipped and gabled roof types are the basic roof systems used with a pitch of between 20º and 35º. The rafter-purlin system is employed in constructing the roofing structure (Fig. 2b). The roof covering is usually made of corrugated aluminium or asbestos sheets. About 9% of the buildings, mainly of landcrete blocks, have thatch finish (Fig. 3a).

It was revealed through key informant interviews in the community that the thatch provides an excellent source of insulation. It has been realized that the thatch roof requires frequent maintenance in the span of three to four years due to rodent attack and decay. As a result of this, a trend has evolved where all new buildings in the community have corrugated aluminium roofing sheets. Also the roofs of some of the old buildings have been replaced with aluminium sheets. This is because it is more durable and requires little or no maintenance. On the contrary, the aluminium sheets create less tolerable conditions because lack of insulation causes more heat radiation into the interior space.

Fig. 3a: Sketch of a building at Nkontompo with thatch roof

Fig. 3b: Landcrete wall with jalousie window

(**Source:** *Author’s Field survey, Nov. 2003*)

Ceilings are not a common feature in the buildings in Nkontompo (Fig. 2b). The few buildings with ceiling found there are constructed of 6mm thick plywood boarding on a 600mm grid system.

The thermal behaviour of a building is basically a function of its form, choice of materials, climate conditions (both macro and micro), and its use (Gut et al., 1999). A typical building structure in the study area consists of many components of different thermal conductance arranged variously in series and parallel. For example, the sides of a house had portions of sandcrete block or sun-dried brick wall into which are inset timber window frames fitted with jalousie or timber battened windows (Fig. 3b). Thus, there were some parts where rooms are separated from the outside by only jalousie timber battens or louver blades (Fig. 4a), in parallel with some parts that had a layer of sandcrete block or sun-dried brick, with coating of plaster (Fig. 4b). The overall thermal performance of the wall is a function of all of these.

Fig. 4a: Sandcrete wall with louver blades window

Fig. 4b: Sun-dried bricks with coating of cement-sand finish in parallel with openings

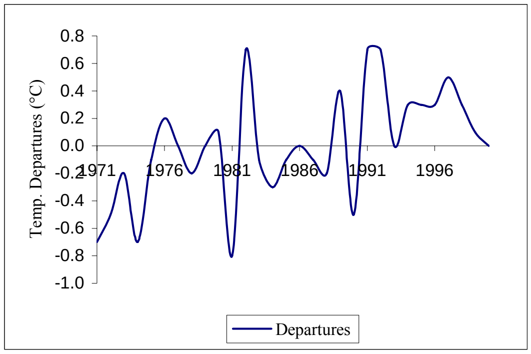
TREND OF TEMPERATURE VALUES AND THEIR EFFECTS ON BUILDINGS IN NKONTOMPO

The average temperature in Nkontompo for the period 1971to 2000 is 26.4°C. Out of the annual temperature values for the thirty year period that of 13 were below the average, while 4 were above and the rest were of the average value (Fig. 5) shows the annual mean temperature departures for the period.
A period of considerable warming was identified from 1971 up to the early 1980s. During this period the mean annual temperature of Nkontompo changed from a low of 0.7°C below the 1971-2000 mean to about 0.2°C above the mean. This presented a mean temperature increase of about 0.9°C over the decade.

From the early 1980s to the end of the 19 90s, there was a steep decline by the end of which the decadal mean fell below the baseline mean. It is significant to note that the mean temperature in mid 1980s, when the declining trend stabilized, were much higher than the mean temperatures recorded from the beginning of the study period up to the early1980s. From the early 1990s, temperature again began to rise, a trend that persisted up to the end of the period. During the whole study period, August was the coolest month for 63 % of the period, while March was the hottest month for 70 % of the period. The average temperature is given in Fig. 6.

(**Source**: *Author's Field survey, Nov. 2003)*

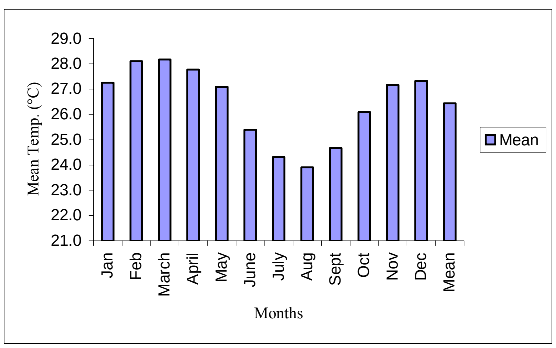
Fig.5: Annual Mean Temperature Departures



*(**Source**: Data from MSD/G, graph by author)*

The average temperature increased at a rate of 0.023 ºC annually, which is about 53 % higher than the global warming rate of 0.15^{0}C per decade (Houghton *et. al.,* 2001, p.26). This means that Nkontompo is approximately 0.69°C warmer than it was 30 years ago in terms of average temperature. Despite the increasing trend of average temperature, the average temperature of the year 1981 (25.6°C) was even lower than that of the year 1971 by 0.1°C. All the months of the year 1981 had lower average monthly values than the long-term average monthly values (Table 1). The trend of the average temperature is shown in Fig. 7.

Fig.6: Annual Mean Temperature



(**Source**: Data from MSD/G, graph by author)

Local residents interviewed had the same response as regard trend of temperature. Generally, average temperature is seen to be risen over the past years.

A rise in temperature can lead to an increase in the rate of reactions and can accelerate many degradation processes. An increase of 10^{o}C doubles the rate of many chemical reactions (Ranson, 1995). High temperatures values lead to high rates of evaporation and volatilisation. High evaporation rates of water from cement mixes can lead to early weakness, poor adhesion and cracking. Building materials, such as bitumen, can soften or melt with high temperatures. Temperature changes can cause dimensional changes in materials, particularly when the coefficient of expansion is high, for example with iron roofing sheets. These changes can cause stresses that, if not accommodated, can exceed the strength of some materials and cause distortion or rupture. Rain falling on a sun-heated surface could lead to a severe quenching shock. Brittle coatings and joints between dissimilar materials can then undergo an initial breakdown, leading to subsequent deterioration. The quality of construction work, especially curing of cement in concrete, could be altered by high temperature conditions.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean
1971	26.2	27.5	27.5	27.3	26.5	25.2	23.5	22.7	23.3	25.6	26.7	26.9	**25.7**
1972	27.1	27.8	27.4	27.4	27.2	24.9	23.1	22.9	23.5	25.4	26.8	26.9	**25.9**
1973	26.9	27.6	28.3	27.2	26.9	25.4	24.7	23.6	24.4	25.7	26.7	27.3	**26.2**
1974	26.7	27.5	27.3	27.2	26.6	24.9	23.6	23.1	23.7	25	26.5	26.7	**25.7**
1975	26.6	33.1	27.3	27.7	27	25.5	23.1	23.4	22.9	25.1	26.9	27.2	**26.3**
1976	28.3	28.6	28.6	28.2	28.1	25.4	23	22.9	24.7	25.5	27.5	28.1	**26.6**
1977	27	27.6	28.3	28.1	27.1	25.3	25.4	24	24.3	26.1	28.4	27.1	**26.6**
1978	27.4	28.1	27.5	27	27	23.7	23.7	23.3	25	28.6	27.7	27.5	**26.4**
1979	27.6	27.9	27.6	27.3	26.7	28.6	23.4	23.8	28.3	25.2	26.2	26.6	**26.6**
1980	27.6	28.3	28.4	28.3	26.9	25.8	24.5	24.5	25.3	26.2	27	27.3	**26.7**
1981	26.6	27.1	27.3	27.4	26	24.3	22.7	22.5	23.6	25.7	27.1	27.2	**25.6**
1982	28.5	28.6	29.1	28.4	26.7	25.4	24.1	24.9	26	26.4	28.1	28.6	**27.1**
1983	28.1	27.9	28.1	27.4	26.6	25.2	24.2	23.5	24.3	25.2	27.1	27.4	**26.3**
1984	27.5	27.7	28.2	27.1	26.6	25.8	24.1	24	23.9	24.2	26.3	27.7	**26.1**
1985	27.2	27.6	28	27.6	26.5	24.6	23.5	22.9	24.4	28.3	27.5	27.6	**26.3**
1986	27.7	28	27.6	29.3	26.9	25.5	24.2	23.7	24.3	26.2	26.8	26.9	**26.4**
1987	26.9	27.5	27.7	28.8	27.6	25.3	24.6	24.3	24.3	26.3	27.6	27	**26.5**
1988	27.2	27.9	27.6	27.8	27.4	26	23.5	23.3	24.3	25.8	27	26.9	**26.2**
1989	24.9	29.7	28.1	28.1	27.9	25.9	25.6	24.8	24.8	25.5	27.8	27.9	**26.8**
1990	27.3	27.8	28.5	27.8	27.3	24.3	23.1	22.5	23.1	25.3	27.1	27	**25.9**
1991	27.6	28.1	28.2	27.9	27.1	27	26.5	27.2	26.1	26.8	26.1	26.7	**27.1**
1992	27.4	28.4	29.1	27.8	26.9	24.7	27.9	25.2	27.1	27.4	26.3	27	**27.1**
1993	27.1	27.9	29.4	27.7	27.1	25.1	23.7	23.4	25.1	26.9	28.1	27.4	**26.6**
1994	27.7	27.8	29.3	27.2	27	25.3	26.1	25.3	23.9	25.4	27.3	27.8	**26.7**
1995	27.7	28	27.7	28.5	27.8	26	24.7	24.1	24.6	25.9	27.2	27.7	**26.7**
1996	27.9	28.6	29.7	28.7	27.6	25.6	24.9	23.7	23.4	25.2	27.5	27.1	**26.7**
1997	27.9	28.4	27.5	26.9	27.9	25.1	24.8	24.6	26.7	27.6	27.8	27.6	**26.9**
1998	27.6	28.7	29	28.7	27.5	24.6	24.6	24	24.6	25.8	27.8	27.6	**26.7**
1999	27.1	26.6	29.2	27.4	27.1	26.2	24.9	24.2	23.9	27.5	26.7	27.5	**26.5**
2000	26.5	26.9	27.7	27.1	27.1	25	23.7	24.7	26.1	26.9	27.3	27.5	**26.4**
Mean	**27.3**	**28.1**	**28.2**	**27.8**	**27.1**	**25.4**	**24.3**	**23.9**	**24.7**	**26.1**	**27.2**	**27.3**	**26.4**

High temperatures with low rainfall conditions lead to longer, drier summers and reduced water supply. This can lead to decreased soil moisture content. Reduced soil moisture content can have consequences on landscaping. Street trees and materials used in urban outdoor spaces could be affected by increased temperature. Insulation materials of cables and plastic components of buildings could be affected.

PRECIPITATION AND RELATIVE HUMIDITY PATTERNS AND THEIR EFFECTS ON BUILDINGS AT NKONTOMPO

The mean annual precipitation for the whole study period (1971 to 2000) is estimated at 1111.3 mm. Of all the months the driest was January with a mean precipitation of 21.6mm, while the wettest was June with 270mm mean precipitation. The annual mean precipitation is shown in fig. 8 and the trend is in Fig. 9. The total annual precipitation has been decreasing significantly at a rate of 3.2 mm annually (i.e. 0.3% annually). Almost all the respondents confirmed that there has been a reduction in intensity of rainfall over the past decade.

Fig. 8: Mean Precipitation

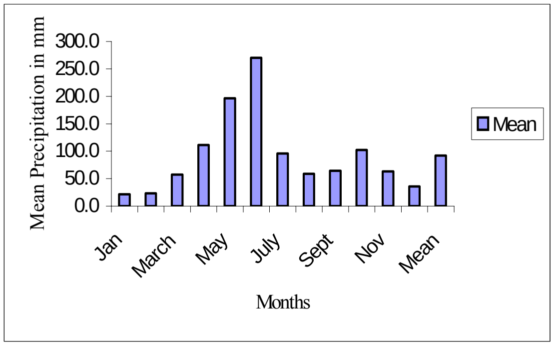
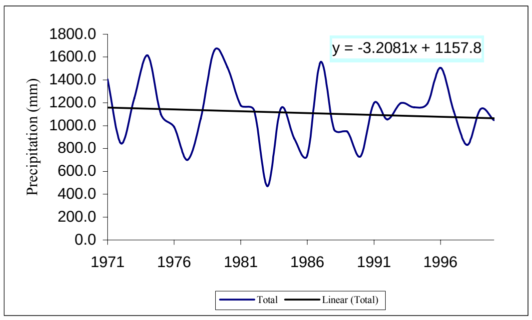


Fig. 9: Annual Trend of Precipitation



(Source: Data from MSD/G, graph by author)

Under natural conditions, water and air fill the spaces between the soil particles. When the moisture content within soil particles is reduced or removed, the latter will tend to move closer together. Changes in the movement of soil can influence that of the building foundations in contact with them and this can in turn affect the performance of the superstructure of the building (Ranson, 1995). About 42% of buildings at Nkontompo have suffered from differential settlement with consequent adverse effect on the foundations, and thus affecting the superstructure. On the other hand, when water is absorbed, the soil tends to move apart. Large movement can occur within clay, for it is capable of absorbing and giving off large quantities of moisture. Movement in sand is for the most part negligible, for they have little capacity to hold water (Ranson, 1995).

The mean annual relative humidity was found to be 75.7 % (Table 2) and the monthly mean relative humidity is in Fig. 10. The average relative humidity varied from 60.2 % in January to 82.4% in August (Fig. 10).

The annual average relative humidity values have significantly increased over the last 30 years at a rate of approximately 0.09 % per year (Table 3). Over the entire period chosen for the study, the minimum and maximum mean values of relative humidity were 71.8% in 1988 and 79.8% in 1996 respectively. The trend of relative humidity over the period is given in Fig. 11.

Table 2: Monthly Relative Humidity (%) of Nkontompo from 1971 to 2000

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1971	68	71	76.3	78.3	78	83.8	85.3	64.5	70	77.5	79	75.8	**75.6**
1972	53.5	68	71	76.3	77.5	81.3	83.8	85.3	83.5	68	71	76.3	**74.6**
1973	63.8	71	71	78.3	76.3	64.5	70	77.5	79	76.3	78.3	70.2	**73**
1974	48	75.3	64.5	87.8	77	79.8	76.5	71.5	83.5	80.5	75.8	74.3	**74.5**

1975	63.8	64.8	69	77	76.3	78.3	81.3	83.8	74.5	78	79	82	**75.6**
1976	22.3	70	64.8	83.5	84.5	83.5	86.5	83.5	80.5	75.8	78.3	81.3	**74.5**
1977	53.5	71	59.8	71	76.3	78.3	81.3	83.8	85.3	83.5	68.8	76.3	**74**
1978	63.8	69	75.3	77.5	79	79.3	82.8	83	78.8	74	77.8	76.5	**76.4**
1979	48	73	60.3	78	77	83	82.5	85.8	83.8	83	81	74.5	**75.8**
1980	81	77	69.3	70	77.5	59.8	73	95.8	78.8	80.8	79.3	71.5	**76.1**
1981	75.8	69.5	65	71	76.3	80.5	83.8	81.3	84.3	83.3	71	76.3	**76.5**
1982	58	67.8	58	69.3	67.8	75.8	79.5	85.8	83.8	86.5	75.3	63.8	**72.6**
1983	72	64.5	70	77.5	79	68	71	76.3	78.3	81.3	75.5	74.2	**74**
1984	64.5	70	77.5	79	79.8	80.5	83	81	84.8	83.3	70	77.3	**77.5**
1985	48	81	75.3	77	78	77	83	82.5	85.8	83.8	71	71	**76.1**
1986	78.5	77.3	77.5	79	68	71	76.3	78.3	69	77	79.8	64.5	**74.7**
1987	68	71	76.3	78.3	81.3	83.8	85.3	83.5	83	81	74.5	78	**78.6**
1988	22.3	64.5	70	77.5	79	76.3	78.3	81.3	83.8	85.3	83.5	61.4	**71.9**
1989	78.5	77.3	64.5	70	77.5	79	82	86	82.8	83	82.5	71.2	**77.9**
1990	72	64.5	75.3	77	78	77	67.8	75.8	79.5	82	83.3	75.8	**75.7**
1991	70.8	69.5	75.5	78	81	82.5	82.8	85.5	83.3	82	78	69.8	**78.2**
1992	22.3	64.5	70	77.5	79	82	86	82.8	83	78.8	74	77.8	**73.1**
1993	53.5	68	71	76.3	78.3	81.3	83.8	85.3	83.5	80	78	73.3	**76**
1994	63.8	64.8	69	77	79.8	80.5	83	81	84.8	83.3	74.5	61.5	**75.2**
1995	48	59.8	73	95.8	78.8	80.8	83.5	86.5	83.5	80.5	75.8	74.3	**76.7**
1996	81	75.3	77	78	77	83	82.5	85.8	83.8	81.8	70.5	81.8	**79.8**
1997	75.8	60.3	69.5	78.8	79.3	84.3	83.3	87.8	83.5	79.8	76.5	71.5	**77.5**
1998	58	69.3	67.8	75.8	79.5	82	83.3	85	83	81	74.5	75.8	**76.2**
1999	72	65	74.3	78.5	77.3	80.5	83.8	81.3	84.3	83.3	78.3	70.3	**77.4**
2000	71.8	53	68.8	76.3	77.8	83.5	84.5	84.3	85.3	82.8	78.3	73.3	**76.6**
Mean	**60.7**	**68.9**	**70.2**	**77.5**	**77.7**	**78.7**	**81**	**82.4**	**81.7**	**80.6**	**76.4**	**73.4**	**75.7**

Data Source: MSD/G)

Wetness in buildings constitutes a potential hazard to health and comfort and a source of aesthetic and material damage. Thermal resistance of external walls is reduced by water content and this lowers the internal surface temperature, increase the likelihood of condensation and causes thermal discomfort (Givoni, 1981). Even when under cover, surfaces can become thoroughly wet, and metals may corrode. The situation can be worse when moisture condenses in relatively inaccessible corners, like eaves of building roofs, from which subsequent evaporation is slow. Dimensional change in timber components is one common defect that was identified at Nkontompo, leading to deformation and cracking. There had been softening of plywood ceiling boarding and disintegration of laminated panels.

Fig. 10: Mean Relative Humidity

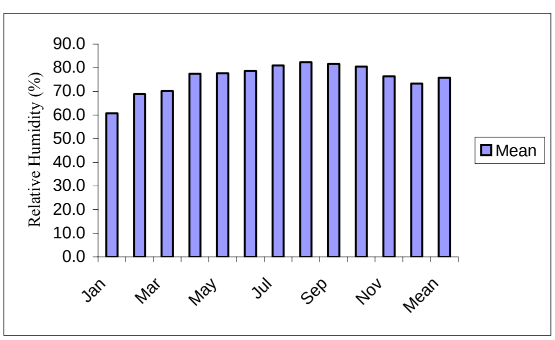
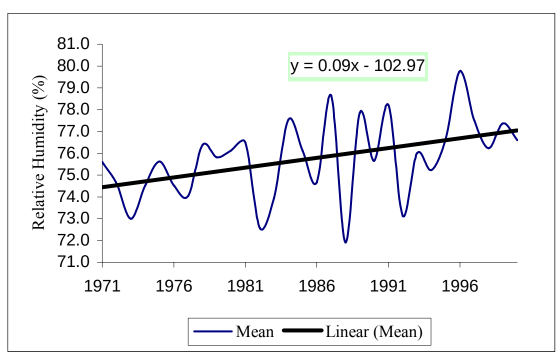


Fig.11: Trend of Relative Humidity



(Source: Data from MSD/G, graph by author)

Timber component close to the ground of some of the buildings that were studied had fungal growth that can be attributed to the very humid condition leaving surfaces damp. This had lead to decay of timber members in varying parts of thirteen buildings that were studied. Fungi survive within a temperature range of 5 to 20ºC, adequate supply of oxygen and moisture content in their environment of 20%. Potential changes in humidity provide favourable conditions for activities of termites on buildings. For instance, dry-wood termites are common in the coastal region (Schreckenbach and Abankwa, 1982)

Table 3: Summary of Calculated Annual Weather Parameters for Nkontompo (Average of 1971-2000)

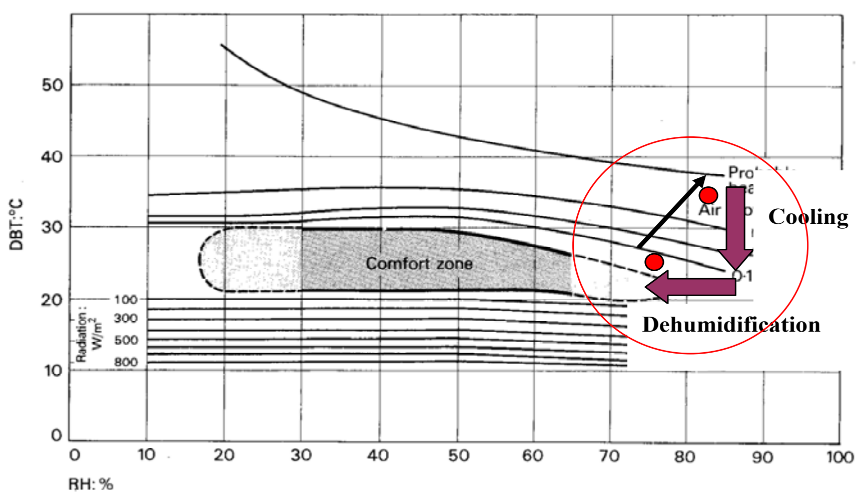
	Description	Unit	Values	Change per year	% Change
1	Annual Average Temperature	°C	26.4 °C	0.023	0.08
2	Annual Average Precipitation	mm	1111.3	-3.2	-0.3
3	Relative Humidity	%	75.7 %	0.09	0.13

(**Source**: Values calculated by author, data from MSD/G)

SHIFT OF CLIMATIC CONDITIONS AT NKONTOMPO FROM THE HUMAN COMFORT ZONE

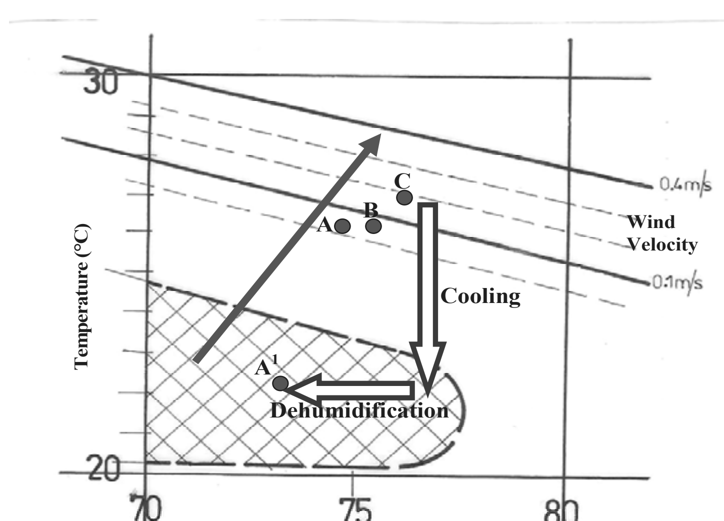
Three sets of decadal means for temperature and relative humidity for the thirty-year period computed and plotted on the Bioclimatic Chart indicated a significant shift from the human comfort zone. These are shown in Fig. 12a and 12b. For the first decade, a temperature of 26.3°C and a relative humidity of 75% were observed as indicated by point A. Similarly those of the second and the third decades were plotted as points B and C respectively (Fig. 12a).

Fig. 12a: Decadal Mean Values of Climate Parameters on Bio-Climatic Chart



(**Source**: Illustration by author, chart from Koenigsberger, 1974)

Fig. 12b: Decadal Mean Values on Bio-Climatic Chart (a blown-up scale)



In all three cases the points are out and above the comfort zone. At point, A if temperature can be controlled but not humidity, a cooling of 3.9°C (Table 4) would be needed to ensure comfort at point A1. Alternatively, if relative humidity can be controlled but not temperature, a dehumidification of 2.0% would be needed to ensure comfort condition at point A1.

On the other hand, if both temperature and humidity are uncontrollable, wind velocity can be provided to ensure comfort condition. From the Bioclimatic Chart, an induced air velocity of 0.04m/s would be needed to ensure comfort.

Similarly at point C, at uncontrollable relative humidity, a cooling of 4.2°C would be needed for comfort at point A1. Uncontrollable temperature, a dehumidification of 3.7% would be needed for comfort at point A1. If both temperature and humidity were uncontrollable, an air velocity of 0.2m/s would be needed to ensure comfort. It can be deduced from the above that as the decadal mean values increase more cooling and dehumidification would be needed to ensure human comfort condition. This implies that the energy needed to ensure human comfort conditions also keep increasing over the years with increasing temperature.

Climate change issues or impacts are of concern to the key informants, however, very little or no response is shown towards evolving adaptive measures in design of the buildings. Generally, all the key informants interviewed have some knowledge on some of the impacts of climate change. The increasing ambient temperature was of most concern to a majority of them.

Table 4: Decadal Mean Values of Temperature and Relative Humidity

Temperature (°C)		Relative Humidity (%)	Required		
Point A1	22.4	73	Cooling (°C)	Dehumidification (%)	Air-Velocity
1971-1980 (A)	26.3	75	3.9	2	0.04
1981-1990 (B)	26.3	75.5	3.9	2.5	0.08
1991-2000 (C)	26.7	76.7	4.2	3.7	0.2

(**Source**: Values calculated by author, data from MSD/G and Bio-Climatic Chart)

LESSONS FOR BUILDING PROFESSIONALS AND POLICY MAKERS

Based on the findings of the study, the following recommendations are made:

- Suitable design techniques should be applied to reduce cooling demand in buildings. The Ministry or Water Resources, Works and Housing should formulate guidelines for the building industry to produce quality homes that will ensure internal comfort conditions. Design of building envelopes should make room for adaptive measures that can effectively ensure internal comfort conditions.
- There is the need for practising Architects and other related professionals and policy makers to consider building technology and the thermal properties of building materials to achieve human comfort conditions in buildings. This will help to produce buildings that are naturally climatically comfortable for tropical conditions like that of Nkontompo and other settlements in Ghana.
- Replacement schedules for existing building stock also presents an advantage. Components such as roofing systems, doors and windows, wall cladding, ceilings are replaced several times in the course of a few decades. This could offer a considerable opportunity for adaptation during the implementation by selecting appropriate materials that can withstand the gradually changing climatic conditions. It is therefore imperative that landlords and other property owners should be effectively guided by qualified professionals within the framework of policy guidelines based on sound research. The Ministry of Water Resources, Works and Housing, the universities and research institutions of the Council for Scientific and Industrial Research (CSRI) should collaborate in this regard.

CONCLUSION

The study revealed that climatic conditions at Nkontompo have changed over the past three decades. Atmospheric conditions are getting warmer with increased temperature and reduced rainfall level. On the other hand, humidity levels have rather risen over the years. This is a phenomenon that would not manifest with reduced rainfall levels. This could be by virtue of the location of the community in the coastal region, where high temperatures are leading to high vapourization of the ocean.

The combined effect of these changes in the climatic elements has led to a shift of atmospheric condition towards an uncomfortable level. There have been associated environmental and physical defects of building elements that have also contributed in diverse ways towards uncomfortable conditions in buildings. A critical wider study needs to be carried out and appropriate responses evolved to ensure that the thermal performance of buildings is improved accordingly.

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