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NET RADIATION OVER THE ROOF TOP IN A TROPICAL CITY

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ABSTRACT

The urban centres are on the increase and the sizes of the towns are growing tremendously. Housing problem has induced the desire to build. The overall energy situation within the town is affected by these increases in the roof surfaces. This paper attempts an analysis of the radiation over the roof surface in the short and long term; and their effects on the overall energy balance. Measurement of net radiation was taken over roof surface for twelve calendar months using two types of net radiation meters. The town was Aba, a continental land area. Results show that there is a steady increase of net radiation over the roof surface from morning till late afternoon. The increase is rather sharp. By late afternoon, the peak is reached and there is a rather very slow and steady decrease in the net radiation till early hours of the morning. This situation calls for serious planning and modification of the urban centre if the physiological comfort of the urban environment must not exceed bearable threshold values.

INTRODUCTION

Urban centres have been on a tremendous increase of late. The increase is both in number and in size. Invariably, most amenities are found in the urban centre and there has been an increasing influx of people to these urban centres. Housing

problem in the urban centres has resulted in increased number of houses. Increased building has subsequently increased the area coverage of roof surface within the urban centre. In the humid tropical environment the most frequently used roofing material has been the corrugated iron sheet. This is probably because this is more durable and more effective during the months of intense rainfall experienced in this environment.

The overall energy situation within the urban environment is more affected by the increased area of roof surface and change from the traditional roof tops to the corrugated iron sheet (1).

In this paper, an attempt has been made to describe and explain the net radiation situation over the roof surface in the short and long term and their effects on the overall energy balance of the urban area of Aba. This will be achieved by:

(a) Identifying the magnitude of the energy balance over the roof surface
(b) Identifying its diurnal and seasonal pattern;
(c) Examine the major contributory factors to the situation and
(d) The implication of all the above on the thermal character of the environment.

Study Area

This study was conducted in Aba, a town in Abia State, Nigeria..Aba is one of the largest commercial centres in Eastern Nigeria and was chosen as the study site because of its rapid growth in size as an urban centre and where there are no large bodies of water close by. The other medium size cities like Port Harcourt, Calabar are rather close to the ocean which have very serious moderating influences on the Micro-Climatic characteristics of the area.

It is located on 7°. 21E and 5°. 06N (Fig. 1) and vary even in elevation, not exceeding 100 meters above sea level (2). The regional climate experienced here is that of high temperatures throughout the year, high relative humidity and high precipitation. Aba can be classed under the Tropical Rainy Climates (3).

MATERIALS AND METHODS

Measurement of the net radiation was taken over the roof top surface (corrugated iron sheet) for twelve months (June to May), once a week with the use of net radiometers. The two types of net radiometers used were Thornthwait Model 603 and the S - I type radiometers.

With a 98%, 30 seconds response time to radiation changes, the instruments were used for five consecutive readings, (7.00 a.m. - 0700 hr; 10.00 a.m. - 1000 hr. 1.00 p.m. - 1300 hr, 4.00 p.m. - 1600 hr, 6.00 p.m. - 1800 hr) within the chosen day. The output from the instruments were fed to a portable millivolts with a maximum output of twelve (12) millivolts and a resistance of one hundred (100) ohms. The calibration used was that quoted by the manufacturer. From the data so generated, the mean monthly values were obtained and used for the analysis of the diurnal and seasonal patterns.

RESULTS AND DISCUSSIONS

Measurements show that the net radiation over the roof surface in the early morning (7.00 a.m.) tended to increase towards the dry months except for the months of December and January where fluctuations were observed in the morning values (Table 1 and Fig. 2). This is attributed to the harmattan haze that is experienced in this area by this time. The minimum net radiation in the morning was recorded in the months of June and January, being about 0.348 gcal/cm²/min (0.243 JKg $m^{-2} s^{-1}$). The maximum was observed in the months of March with a value of 0.437 gcal/cm²/min (0.305 Jkg $m^{-2} s^{-1}$). There was a clear pattern of decrease towards the rains (Fig. 2).

Increased insulation received at 10.00 a.m. (100hr) caused an increase in net radiation over this surface. The minimum net radiation by this time was 0.430 gcal/cm²/ min (0.300 Jkg m^{-2}

s^{-1}), recorded in June; while the maximum value was about 0.500 gcal/cm² min (0.349 Jkg $m^{-2} s^{-1}$), recorded in March. The pattern here was an increase towards the dry months while there was a decrease towards the rains. This pattern is simultaneous with the pattern of global radiation resulting from the receipt of insulation. The monthly average values for this time was about 0.452 gcal/cm²/min (0.315Jkg$m^{-2}s^{-1}$). However, the variation between the values of late morning and early morning was substantial ranging from 0.048 gcal/cm²/min (0.032 Jkg $m^{-2} s^{-1}$) in the transition month of April to the highest of 0.128 gcal/cm²/ min (0.089 Jkg $m^{-2} s^{-1}$) in January (Fig. 2). The variation decreases towards the rains, with the lowest value at the peak of the rains. Thereafter it increases towards the dry months. For instance, the value of the variation was about 0.082 gcal/cm²/min (0.057 Jkg $m^{-2} s^{-1}$) in June and July, it rose to 0.089 gcal/cm²/min (0.062 Jkg $m^{-2} s^{-1}$) and 0.128 gcal/cm²/min (089 Jkg $m^{-2} s^{-1}$) in December and January respectively (Fig. 3).

In the early afternoon (1.00 p.m., 1300hr), the value rose to 0.605 gcal/cm²/min (0.422 Jkg$m^{-2}s^{-1}$) as the monthly average. The minimum for this period, however, was still recorded in June, being 0.559 gcal/cm²/min (0.390 Jkg $m^{-2}s^{-1}$); while the maximum was about 0.646 gcal/cm²/min (0.451 Jkg $m^{-2} s^{-1}$), recorded in February. The variation again was substantial. It is interesting to note that the variation between late morning and early afternoon exceeded the variation between early morning and late morning throughout the year (see Fig. 3).

June and July had variation of 0.129 and 0.143 gcal/cm²/min (0.090 and 0.10 Jkg $m^{-2} s^{-1}$) respectively; while the variation between late morning and early afternoon in October and November stood at 0.173 and 0.177 gcal/cm²/min (90.121 and 123 Jkg $m^{-2}s^{-1}$) respectively. However, the highest variation value was recorded during the transition to dry months. The monthly average value of this time was about 0.605 gcalcm²/min (0.422 Jkg $m^{-2}s^{-1}$).

Table 1: Average Monthly Net Radiation Over Roof Top in ABA (gcalcm²/min

	J	J	A	S	O	N	D	J	F	M	A	M
7am	0.348	0.352	0.358	0.356	0.366	0.368	0.358	0.348	0.423	0.437	0.410	0.366
10am	0.430	0.434	0.433	0.439	0.441	0.449	0.447	0.476	0.475	0.500	0.456	0.442
1pm	0.559	0.577	0.571	0.616	0.164	0.610	0.631	0.610	0.646	0.632	0.620	0.578
4pm	0.582	0.596	0.604	0.608	0.607	0.608	0.619	0.616	0.628	0.625	0.616	0.586
6pm	0.381	0.380	0.379	0.390	0.400	0.404	0.412	0.415	00.420	0.429	0.392	0.391

Source: Drived From Field Date

By late afternoon (4.00pm - 1600 hr), net radiation over the roof surface increased (Fig.2). The minimum value recorded in June was about 0.582 gcal/cm²/min (0.406 Jkg m² S⁻¹). The seasonal trend observed was an increase towards the dry season and a decrease towards the rains. The monthly average value being about 0.608 gcal/cm²/min (0.424 m² S). This showed a smaller variation on the average than those of the early afternoon.

It is interesting to note that from transition months to the dry-months and throughout the dry season, the values of net radiation were higher in the early afternoon than those of the dry season, the values of nèt radiation were higher in the early afternoon than those of the late afternoon, whereas during the value of the late afternoon were higher than those of the early afternoon. this is an indication that the root surface reached maximum absorption rate, early (early afternoon) during the transition and dry season whereas during the rainy season the roof surface still received and absorbed energy up till late afternoon. The variation between the early and late afternoon was as low as 0.018 gcal/cm²/min (0.013 Jkg m⁻² S⁻¹)in the dry months, which exhibited the peak variation values. (Fig. 3).

By evening (6.00 p.m - 1800 hr), the value of net radiation dropped. The maximum value recorded in March was 0.429 gcl/cm²/min (0.299 Jkg m⁻²S⁻¹). The usual seasonal trend of

increase towards the dry season and decrease towards the rains was also noted for this period. The monthly average of this period was 0.39 9 gcal/cm²/min (0.278 Jkg m⁻²s⁻¹). The overall-all-time, all season average of net radiation over the roof surface was noted to be 0.488 gcal/cm²/min (0.341 JKg m⁻²s⁻¹).

It is interesting to note that the variation between late afternoon and evening is the highest observed all througn the day (Fig. 3).Table II. and Fig. 4 show the pattern of the average net radiation over the roof top surface.

Table II. Average Net Radiation Over Roof Top Surface (gcal/cm²/min)

	Monthly Average	Dry Season Average	Wet Season Average
7 a.m	0.275	0.392	0.366
10a.m	0.452	0.472	0.441
1 p.m	0.605	0.630	0.593
4 p.m	0.608	0.622	0.601
6 p.m	0.399	0.419	0.390

Sources: Derived from Field Data

It is instructive to note that in the dry season, the peak was reached in the early afternoon; whereas in the rains the peak was reached in the late afternoon, a situation that has been linked to the fact that this surface (roof) receives maximum insulation early in the dry season whereas there is a lag in time during the rains. The range of variation of net radiation over the roof top surface was least during the late afternoon and the evenings. This meant that throughout the year, there was less variation in the net radiation over the roof surface especially in the late afternoon and evenings (Fig. 2 and 3)

The seasonal pattern is exhibited by Fig. 4, which depicts that on the average, the dry season conditions are higher. This is as a result of uncreated radiation received during this period.

Generally, therefore, the pattern of radiation over the roof surface has been that of increase towards the afternoon and dry months and a decrease towards the night and rainy season. This is because the dry months exhibit higher insulation as a result of increased intensity and longer hours of sunshine, quite apart from the less cloudiness.

IMPLICATION

The ever-increasing proportion of roof surface with corrugated iron sheets in the urban centres has serious implication for the total energy balance of the town and subsequently the thermal regimes. There has been a steady increase in the total energy balance over the urban area of Aba (1). It is also interesting to note that in 1994, the roof surface contributed as much as 154.6gcal/cm^2/min to the energy balance of the urban Aba (Ekanem 1997). The high net radiation over the roof surface is an indication that there will be surplus energy over the urban atmosphere. This is because of the increased coverage of surface. This surplus energy will be converted to sensible heat and this is what contributes to the high temperatures of the urban environment even in the night. The consequences of this is the uncomfortable situation in terms of thermal regimes. This will consequently affect the human activities within the urban centre/environment.

RECOMMENDATION

Based on the results of the investigation, it is possible to make a few recommendations that would help to effectively control and regulate the micro - climatic environment of the roof top. It is possible to cool the roofs indirectly. This could be in the form of evaporative cooling. It can be passive and indirect by 74 providing a shaded water pond over an uninsulated roof. When the water is in thermal contact with the roof and the roof itself is made of materials with high thermal conductivity, the combined water and roof structure serve as an integrated "cold" storage. The cooling temperature follows the water temperature closely. Consequently, the ceiling serves as passive cooling

panel for the space below. In all these, the roof should be able to structurally support the water pond (about 200 - 400 km^2 depending on the system) and provided with a "perfect" waterproofing. It should be noted, however, that once the "perfect" water proofing is installed, it need to be protected from sharp changing weather condition which are likely to destroy the mechanism (4). The other mechanism to reduce the excess net radiation over the roof surface is by "grass roofing". With concrete roof, structurally, designed for proper drainage, short grasses, could be planted on the roofs. This will provide sources of expenditure of the surplus energy quite apart from shading the roof from the direct absorption of the solar radiation.

It is possible to lower the air temperatures by modifying the albedo of the roof tops. The average albedo of the roofs determines the radiation exchanges from the roof surface. By colouring the roof white and yearly repainting, it might be possible to lower the radiation balance by increasing the values of albedo over the roof surface. Under this condition, average temperature of the roof surface will be lower than the average regional air temperature, and because cool air is heavier than warm air, it will sink into the city street. It will then be possible to achieve a day time temperature lower than in the surrounding areas.

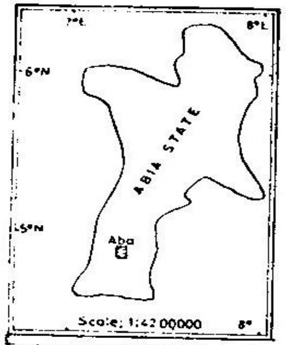


Fig. 1a: Abia state showing the location of Aba (study area)

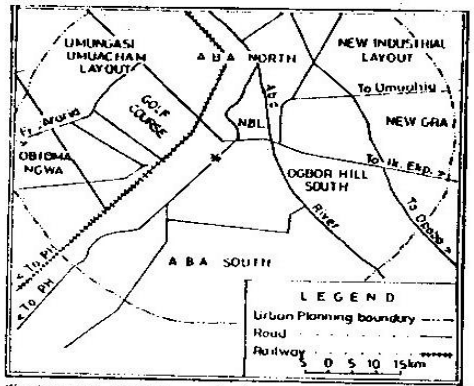
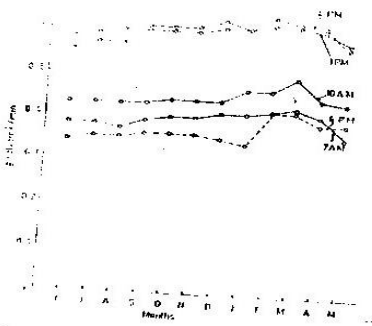


Fig. 1b: Point of measurement ; *



... MONTHLY NET RADIATION OVER ROOF TOP IN ABA.

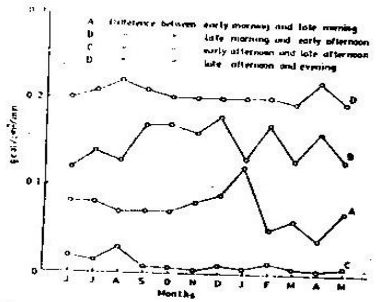


Fig 3. VARIATION BETWEEN EACH PERIODS

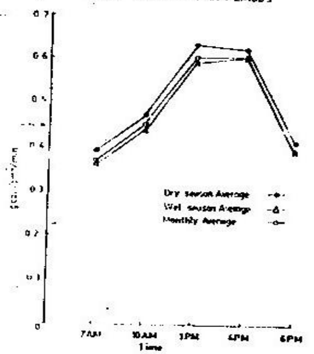


Fig 4 AVERAGE NET RADIATION OVER ROOF TOP SURFACE IN ABA

REFERENCES

1 Ekanem, E. M. Urban Surface Energy Balance in a Humid Tropical City of Aba: Unpublished PhD Thesis,

2 Ofomata G. E. K. (1975) "Relief" in Ofomata GEK Nigeria in Maps; Eastern States. Ethiope Publishing House, Benin City, PP. 8 -9 1975.

3 Koppen W. (1918) : "Klassification der Klimate nach Temperatu Niederschlag and Jahveslauf" Petermanns Geographischs Mitteilungen. 64: 193 -248. 1918.

4 Givoni B. Design for Clomiates in Hot/Dry Cities in Oke T. R. Urban Climatology and its Application with special Regards to Tropical Areas. WMO Teach. Note No. 652 PP. 467 -513. 1986.

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