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RADIATION BALANCE ON THE CONCRETE SURFACE IN AN URBAN CITY

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ABSTRACT

Rapid urbanisation sometimes leads to severe problems associated with environmental deterioration, unhealthy living conditions, shortage of water etc. If climatological information, principles and experience were incorporated in the planning of rapidly growing urban areas, most of the above problems could have been minimized. Results show that the energy balance over concrete showed diurnal and seasonal variations in the radiation balance pattern. The monthly overall average radiation over the concrete surface was $0.476 \text{ g cal/cm}^2/\text{min}$ ($0.332 \text{ JKg m}^{-2} \text{ S}^{-1}$). The diurnal pattern showed an increase from morning till late afternoon and then decreases. The seasonal pattern showed a marked dry season peak. However, the general over radiation balance over the concrete surface is higher than that of other surfaces like grass, ground or water. This higher radiation balance has implications for the energy regime of the urban environment and physiological comfort index of the urban environment.

INTRODUCTION

Now-a-days urbanization is taking place at an extremely rapid rate because of increasing population. This rapid urbanization sometimes may lead to severe problems associated with environmental deterioration, unhealthy living conditions, shortage of water etc. If climatological informations, principles and

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experience were incorporated in the planning of rapidly growing urban areas, most of the above problems could be solved. Urbanization has impacts on urban climates (1 and 2) Rapid growing buildings which are mainly concrete, roads and concrete floors etc in urban areas have effects on radiative cooling/heating, and wind circulation. The type of materials and designs of buildings/houses etc. should depend very much on climatic elements and their extreme values. Therefore, planners and designers must consider the climatic factors and extreme values of climatic elements before engineering constructions of building of houses, drains and concrete floors in urban areas.

This paper attempts to study the radiation balance of the concrete surface within the urban environment. This is done with the intention to determine the magnitude of the net radiation over the concrete surface. This becomes more serious when viewed from the fact that most buildings or structures within the urban environment is done with cement concrete. The results of this study are believed to be very useful in the understanding of the energy character and regime of urban environment. The focus of this study is to examine the character of the net radiation of the concrete cement surface in an urban setting.

MATERIALS AND METHODS

STUDY AREA

This study was conducted in a humid tropical city of Aba, a settlement established in 1901 as a military camp. It is an important commercial centre east of the Niger. Located at $5^{\circ}.06'N$ and $7^{\circ}.21'E$, (Fig 1), Aba is a moist tropical city with well over 2000mm of rainfall. Temperatures are always high throughout the year with high relative humidity. The city was chosen because of its continentality, located some 150 kilometers from the ocean and its medium size of about 12 kilometers in diameter.

The city is generally below 100 meters above sea level and can be classed as a tropical rainy hot climates.(3 and 4).

Measurements of net radiation over the concrete surface were taken with the use of Thornthwait model 603 net and type

S-1 radiometers and weekly measurements were obtained. On specific days of measurements, five consecutive readings were taken at 7.00 am (0700hr), 10.00am (1000hr) 1.00pm (1300hr), 4.00pm (1600hr), and 6.00pm (1800hr). These readings were done for twelve calendar months (June to May), to obtain both the diurnal and seasonal variation of the net radiation over the surface. However, it is the mean monthly values that were used for the analyses. The output from the instrument were fed to a portable millivolt with a maximum output of twelve millivolts and a resistance of one hundred (100 hours) ohms. The calibration used was that quoted by the manufacturer with a 98% accuracy level and 30 seconds response time to radiation changes.

RESULTS AND DISCUSSION

Table I shows the average net radiation over concrete surface. The net radiation over the concrete surface showed higher value than that of ground, grass and water (4). Results of measurements indicate that the monthly overall average net radiation over the concrete surface was $0.476 \text{ gcal/cm}^2/\text{min}$ ($0.332 \text{ Jkg m}^{-2} \text{ S}^{-1}$) as opposed to $0.442 \text{ gcal/cm}^2/\text{min}$ ($0.308 \text{ Jkg m}^{-2} \text{ S}^{-1}$), and $0.456 \text{ gcal/cm}^2/\text{min}$ ($0.318 \text{ Jkg m}^{-2} \text{ S}^{-1}$) and $0.462 \text{ gcal/cm}^2/\text{min}$ ($0.322 \text{ Jkg m}^{-2} \text{ S}^{-1}$) of water, grass and bare ground surfaces respectively (4).

The early morning (0700hr) pattern rose from the minimum of $0.234 \text{ gcal/cm}^2/\text{min}$ ($0.163 \text{ Jkg m}^{-2} \text{ S}^{-1}$) recorded in June, the near peak of the rains, to a maximum of $0.428 \text{ gcal/cm}^2/\text{min}$ ($0.299 \text{ Jkg m}^{-2} \text{ S}^{-1}$) recorded in the month of February. The early morning average stood at $0.369 \text{ gcal/cm}^2/\text{min}$ ($0.257 \text{ Jkg m}^{-2} \text{ S}^{-1}$). By late morning (10.00hr) an increase was recorded for the net radiation. This is as expected, since there was a general increase in the global radiation by late morning as a result of the increased insolation. The least of the values of net radiation for the late morning period over concrete was recorded between June and August with a value of $0.419 \text{ gcal/cm}^2/\text{min}$ ($0.292 \text{ Jkg m}^{-2} \text{ S}^{-1}$); while the highest was

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observed in February with a value of $0.494 \text{ gcal/cm}^2/\text{min}$ ($0.345 \text{ Jkg m}^{-2} \text{ S}^{-1}$). Thereafter, there was a steady decrease in the value as the rains set in.

By early afternoon (1300hr), there was a marked increase in the net radiation over the concrete surface. The minimum recorded value of this component of radiation was $0.542 \text{ gcal/cm}^2/\text{min}$ ($0.378 \text{ Jkg m}^{-2} \text{ S}^{-1}$) in June. Thereafter, there was a steady increase until the peak of $0.622 \text{ gcal/cm}^2/\text{min}$ ($0.434 \text{ Jkg m}^{-2} \text{ S}^{-1}$) observed in February which was the heat of the dry season. The monthly average value of this component of radiation at this time was noted to be $0.588 \text{ gcal/cm}^2/\text{min}$ ($0.410 \text{ Jkg m}^{-2} \text{ S}^{-1}$). In the late afternoon (1600 hr), the net radiation over the concrete surface was not too different from that of the early afternoon. For instance, the minimum value was recorded in June ($0.577 \text{ gcal/cm}^2/\text{min}$) ($0.398 \text{ Jkg m}^{-2} \text{ S}^{-1}$); while the peak was also recorded in the month of February being $0.619 \text{ gcal/cm}^2/\text{min}$ ($0.432 \text{ Jkg m}^{-2} \text{ S}^{-1}$). However, the overall monthly average for this period differs from that of the early afternoon. At this point in time the value of the monthly average was $0.591 \text{ gcal/cm}^2/\text{min}$ ($0.412 \text{ Jkg m}^{-2} \text{ S}^{-1}$). In the evening (1800hr), the minimum value of net radiation was observed in July with a value of $0.363 \text{ gcal/cm}^2/\text{min}$ ($0.253 \text{ Jkg m}^{-2} \text{ S}^{-1}$); while the peak indicating a maximum for this period was $0.423 \text{ gcal/cm}^2/\text{min}$ ($0.295 \text{ Jkg m}^{-2} \text{ S}^{-1}$) recorded in February. The average for this period was $0.389 \text{ gcal/cm}^2/\text{min}$ ($0.271 \text{ Jkg m}^{-2} \text{ S}^{-1}$). The pattern, therefore, was a steady increase from the heart or peak of the rainy season until the peak of the dry season. Thereafter the values began to decrease more sharply till it hit the minimum.

Table 1: Average Net Radiation over concrete surface (gcal/cm²/min) (* Jkg m⁻² S⁻¹)

Time	Monthly Average		Dry Season Average		Wet Season Average		Range	
		*		*		*		*
0700 hr	0.369	0.257	0.400	0.279	0.353	0.246	0.336 – 0.428	0.234 – 0.299
1000 hr	0.444	0.310	0.476	0.332	0.428	0.299	0.491 – 0.494	0.292 – 0.345
1300 hr	0.588	0.410	0.616	0.430	0.574	0.400	0.542 – 0.622	0.378 – 0.434
1600 hr	0.591	0.412	0.615	0.429	0.579	0.404	0.557 – 0.619	0.389 – 0.432
1800 hr	0.389	0.271	0.412	0.289	0.377	0.263	0.363 – 0.423	0.253 – 0.295
Mean	0.476	0.332	0.504	0.352	0.462	0.322	0.443 – 0.517	0.309 – 0.361

Source: Derived from Field data.

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From the table above, it is obvious that the difference between the morning values of the net radiation and those of afternoon was much, especially during the dry season. A difference of well over 0.140 gcal/cm²/min (0.098 jkg m⁻²s⁻¹) was noticeable between morning and afternoon values of the net radiation during the dry season. The difference in values of the net radiation between the periods was not that wide during the wet season. Figs 2 and 3 show graphically the pattern of the net radiation over the concrete surface.

It is pertinent to note here that in the dry season the peak of the net radiation was reached in the early afternoon whereas in the rains the peak was reached in the late afternoon; a situation that has been associated with the fact that concrete surface receives and retains maximum energy early in the dry season whereas there is a lag in the time during the rains. Generally, therefore, the pattern of the net radiation over the concrete surface has been that of increase towards the afternoon and dry months and a decrease towards the night and wet months. This is attributed to not only the reduced insolation, cloudiness but also to the character of the surface. The dry months exhibit higher insolation and the water contents of the surface is very low.

IMPLICATIONS:

Most structures in the urban environment are made with concrete and of recent there is this increasing changes of the surface surrounding buildings from the natural to concrete in the urban environment. This has serious implications for the total energy balances of the urban environment and the subsequent thermal regimes. The high net radiation over the concrete surface which incidentally is higher than those of the natural surfaces like grass and bare grounds is an indication that there will be excess energy over the urban atmosphere. This surplus excess energy will be converted to sensible heat as there are less avenues of the expenditure and disposition of the energy in the urban environs. This will contribute to higher urban temperatures even into the night. The consequence of this will be the highly uncomfortable situation in terms of the thermal regime of the environment. This will have great effects on human activities within the urban environment.

RECOMMENDATIONS

Based on the results of this study, it is pertinent to make a few recommendations that could help to effectively reduce and regulate the micro climatic environment of the area where concrete surfaces are predominant.

It may be possible to counter the effects of the excess energy by providing a form of evaporative cooling. This could be in the form of pools of water. This could provide a source of expenditure of the surplus energy quite apart from the cooling that will result as a direct effect of the evaporation.

It is recommended that all structures erected or laid with concrete should be smoother and painted with white colour. This will reduce the rate of absorption of the energy by increasing the albedo of the surface. This will subsequently reduce the energy emission by this surface. Also planting of shed trees over all surfaces that are of concrete will be of immense help as it will cut off the direct absorption of insolation by these surfaces and structures quite apart from the fact that it will increase the rate of evopotranspiration. Grass lawn will be of greater benefit than surfaces laid to concrete. Grasses show lower radiation balance

and also provide means of expenditure of energy. Therefore, where concrete can be avoided grassing should be put in their place. Where it cannot be avoided areas near to it should be planted with grass as this will encourage a more conducive adverted energy system within the environment, reducing excess heat.

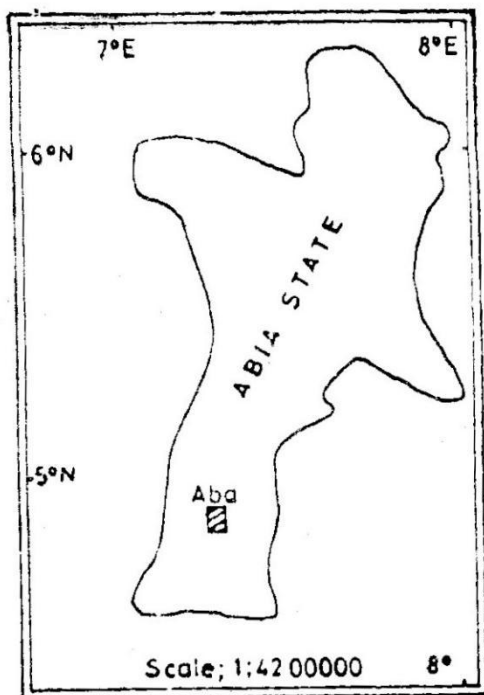


Fig. 1a. Abia State showing the location of Aba (Study Area).

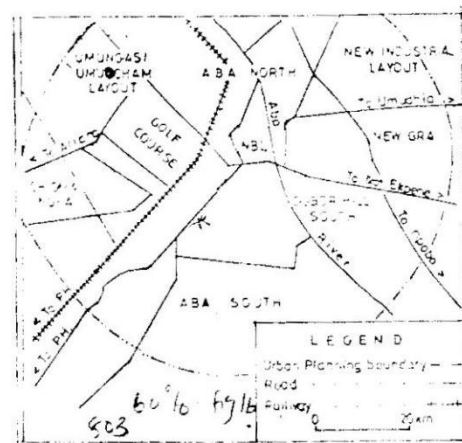


Fig. 1b. Point of measurement

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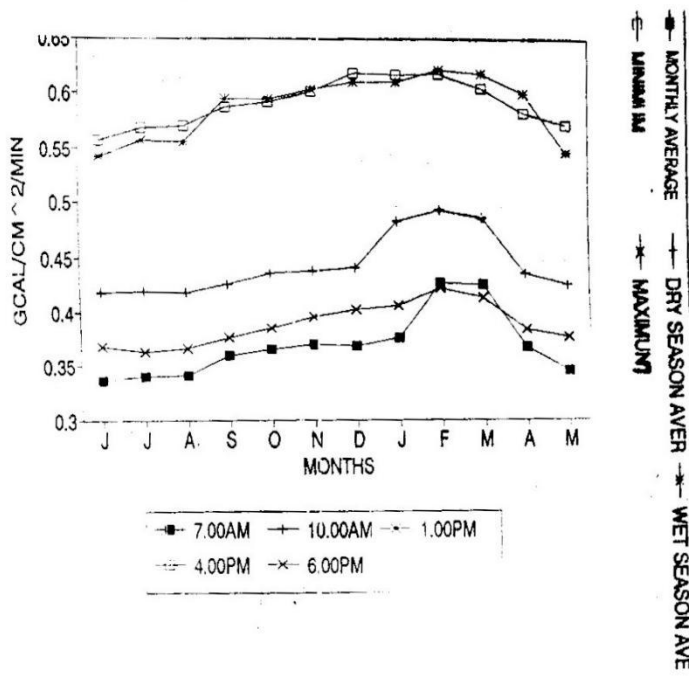


Fig. 2. Average net radiation over concrete surface.

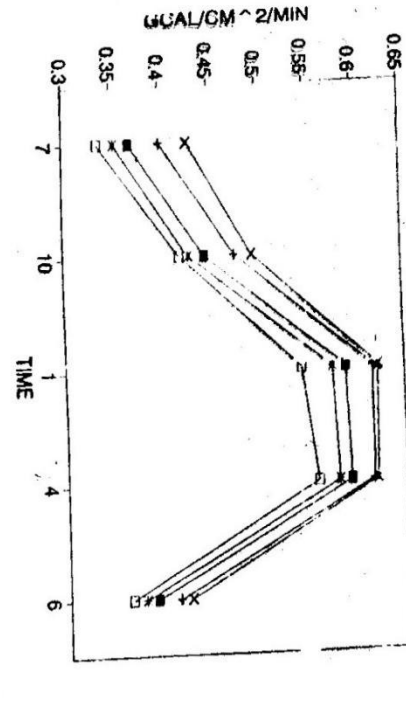


Fig. 3. Monthly average net radiation over concrete surface.

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