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ENERGY BALANCE OVER TARRED ROAD IN A HUMID TROPICAL CITY OF ABA

EKANEM EKANEM

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ABSTRACT

There is a heightened public awareness to improve conditions in our urban centres, and many governments have even engaged consultants to help them in the improvement of urban centres. One major way of the improvement is in the tarring of urban roads. These have implications for the urban environment. This study aims at examining urban center typified by Aba, a medium size city in the humid tropics. Five consecutive measurements were taken over the tarred road surface, for one calendar year with two net radiometers. Results show that there is a marked seasonal and diurnal pattern of the energy balance over the tarred road surface.

The texture of the road, the colour and its ability to absorb heat readily left the energy balance increasing steadily till late afternoon thereafter it drops rather slowly till late in the night. The seasonal pattern showed a marked peak in the dry season months of February and March. These results have serious implications for the urban energetic in the face of increasing proportion of areas paved with tarred material.

The high radiation balance over the tarred road surface invariably means that the surplus energy will be used to heat the air in the urban center leaving the urban temperatures higher than what it should be. This consequently has effect on the heat island regimes and the physiological comfort regimes of the environment.

KEY WORDS: Energy Balance, Tarred Road, Aba, physiological comfort

INTRODUCTION

There is a heightened public awareness to improve conditions in our urban centres, and many governments have engaged consultants to help them in the preparation of master plans to guide the growth of their cities. Mabogunje (1981) had noted that such actions represent activities in the present, and as a means of tackling the set of overwhelming problems created by the very rapid rates of urbanisation in the country. They can be criticized for being at best short term in conception and ad hoc in their application. The present uncontrolled operation of the urbanization process will only lighten the disequilibrium existing in the urban centres.

Temperature in the urban centres are noted to be higher than those of adjacent rural environment. These high temperatures could be attributed to increased sensible heat available in the urban environment. This is because in the urban environment the disposition of energy is in the conversion to sensible heat which goes to warm the urban air.

Tarred road surface has been on the increase in the urban centres, and in fact, it is possible to use the length of tarred road available in an urban

EKANEM EKANEM: Department of Geography University of Uyo, Uyo, Nigeria

environment as an index of growth. The increase in the surface area of the tarred road surface is bound to affect the energy regime of the urban environment; it is therefore not out of place to note the energy balance over the tarred road surface, within the environment

Human activities can alter the energy balance and therefore the thermal characteristics of an area in a great variety of ways. Examples range from local, deliberate and beneficial alteration (e.g .the effects of a glass green house) to unconscious and potentially adverse interference at the global level (e.g. the impact of carbon dioxide accumulation in the atmosphere). A very useful way of examining the effect of human disturbance on the energy balance a little further is to consider the mechanism of interference. Humans are able to change inputs, transfer the outputs of radiation and thus can alter temperature patterns at different scales by changing the character of the earth surface, and altering the nature and composition of the air. O' Hare and sweeney (1986) noted that anthropogenic alteration to the composition of the atmosphere are responsible for contributing to local and regional modification of climate. Many urban areas are 0.5-1.^{0}C warmer than rural environment on an average annual basis and have winter minimum temperature 1-3^{0}C higher than their rural surrounding. (O' Hare and sweeney 1986).

AIM AND OBJECTIVE

It is the aim of this study to examine the energy balance over the tarred road surface in Aba. The specific objectives of this study are:

a) to determine the magnitude of the energy balance over the tarred road surface;

b) to examine the diurnal and seasonal variation of the energy balance over ~~the~~ tarred road surface;

c) to determine the major factors responsible for the energy balance over the tarred road surfaces; and

d) to examine the implications of the above for the urban environment.

For this study, it is postulated that the analysis of data obtained will help in the determination/ prediction of the energy balance over the tarred road surface in the humid tropical environment.

MATERIALS AND METHODS

To obtain the net radiation over the tarred road surface, measurement of net radiation was taken over the surface for twelve calendar months of the year (June to May) with the use of net radiometers. There were two types of net radiometers - the Thornthwaite's model 603 and the S - I radiometers - in use. The instrument has a 98%; 30 seconds response time to radiation change.

It has a direct sensing element lying horizontally at the center of a supporting split brass 6mm in diameter, with cellophane windows 50mm in diameter sealed to the upper and lower halves of the ring. The output was fed to a portable millivolt meter having a maximum output of twelve (12 mv) millivolts and a resistance of 10Ohms. The calibration used was that quoted by the manufacturer. These measurements were taken on a weekly basis and to extradict the diurnal pattern, the measurements were obtained for five consecutive times (7.00 am, 10.00am, 1.00pm. 4.00pm and 6.00pm) within the chosen day. However, it was the mean monthly values that were used for the analysis of the diurnal and seasonal patterns.

STUDY AREA

Aba, a town in the recently created Abia state was chosen as the study area because it was the largest humid tropical area without large bodies of water close by, that can moderate the effects of the urban energetics. The city is located on 7°21 E and 5°06′N (Fig.1a) and is generally below 100 meter above sea level (Ofomata 1975). Located in the eastern part of Nigeria the town has a diameter

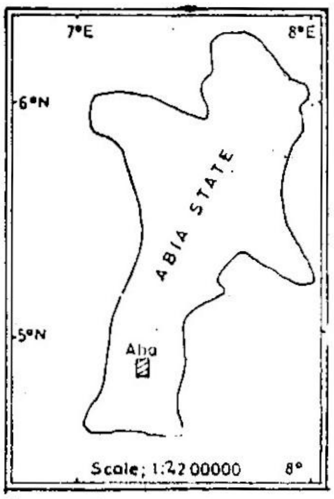

Fig. 1a: Abia state showing the location of Aba (study area)

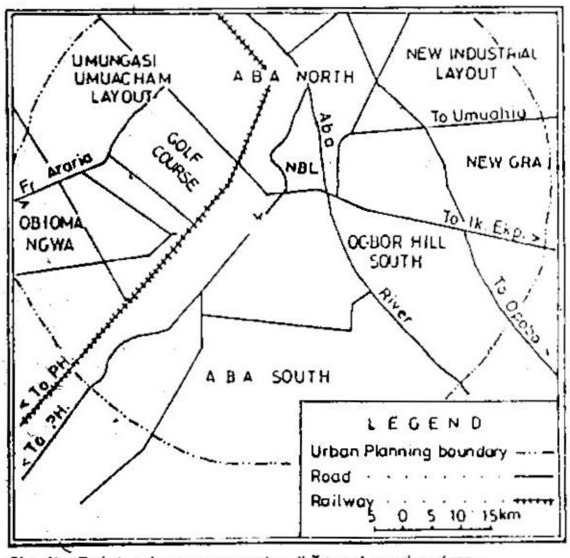

Fig. 1b: Point of measurement; * Tarred road surface.

of 12 kilometers (Fig.1b) with a tropical rainy hot climate (Aw) after koppen (1948) classification scheme.

RESULTS AND DISCUSSION

Measurements show that the net radiation over the tarred road surface in Aba, was high. For instance, in the early morning (7.00am), the minimum value which was observed in the month of July was about 0.344gcal/cm^2/min. Incidentally, July was within the heart of the rainy season in this locality. Thereafter, there was a steady increase in the amount of net radiation until in March, when the peak value of 0.440gcal/cm^2/min was recorded. The month of March, however, was in the transition period between the dry and wet seasons. From then on the value began to decrease, indicating a pattern of decrease with the rains until the peak of dry season. However, the monthly average value of this eary morning period was put at 0.377gcal/cm^2/min. Table 1 shows the average monthly values of net radiation measured over the tarred road surface in Aba.

By late morning (10.00am), the value of the net radiation increased from what it was in the early morning with the minimum value of about 0.422gcal/cm^2/min, observed in June, a little lower than the maximum value recorded for the early morning (Table1). The maximum for this late morning was recorded in February and this was 0.52gcal/cm^2/min. The earlier pattern of decrease towards the rains and increase towards the dry season was also observed with the monthly average of about 0.450gcal/cm^2/min. By early afternoon (1.00pm), the minimum value, recorded also in June, was 0.502gcal/cm^2/min, while the maximum value of 0.642gcal/cm^2/min was recorded in February and the monthly average stood at 0.596gcal/cm^2/min. The pattern was also a steady decrease towards the rains and an increase towards the dry months. In the late afternoon (4.00pm) when the full impact of insolation had been received, the minimum value of net radiation, recorded in June, was 0.571gcal/cm^2/min, and the maximum, observed in January, was 0.614gcal/cm^2/min, with a monthly average of 0.597gcal/cm^2/min (Table 1). In the evening (6.00pm) the net radiation value was higher than that of the morning, with the minimum of 0.432gcal/cm^2/min recorded in March. The seasonal trend was not quite different from those of the other time periods, as there was an increase towards the dry month; while there was a steady decrease towards the wet months within the year. The monthly average for the evening was observed to be 0.397gcal/cm^2/min. With higher values of the net radiation in the evening than in the morning, and there are strong indications that there is some urban heat island effect in Aba especially in the night. This was as a result of the continuous existence of surplus net

TABLE 1: AVERAGE MONTHLY NET RADIATION OVER TARRED ROAD AT ABA (gcal/cm2/min) (1993-1994)

TIME	J	J	A	S	O	N	D	J	F	M	A	M	TOTAL	AVG
7.00AM	0.346	0.344	0.348	0.370	0.369	0.372	0.365	0.368	0.439	0.440	0.395	0.363	4.529	0.377
10.00AM	0.422	0.428	0.429	0.443	0.446	0.443	0.441	0.484	0.502	0.492	0.441	0.429	5.401	0.450
1.00PM	0.552	0.565	0.564	0.596	0.602	0.600	0.612	0.612	0.642	0.622	0.606	0.556	7.149	0.596
4.00PM	0.571	0.586	0.595	0.597	0.600	0.603	0.613	0.614	0.610	0.610	0.589	0.579	7.167	0.597
6.00PM	0.375	0.375	0.373	0.388	0.399	0.401	0.406	0.408	0.421	0.432	0.395	0.390	4.763	0.397

SOURCE: DELIVERED FROM FIELD DATA

TABLE 2: AVERAGE SEASONAL NET RADIATION OVER TARRED ROAD SURFACE AT ABA ($gcal/cm^2/min$) 1993 - 1994)

TIME	MONTHLY AVERAGE	DRY SEASON AVERAGE	WET SEASON AVERAGE	RANGE OF NET RADIATION
7.00a.m.	0.377	0.403	0.363	0.344 - 0.400
10.00a.m.	0.450	0.480	0.435	0.422 - 0.502
1,00p.m.	0.596	0.622	0.580	0.522 - 0.642
4.00p.m	0.597	0.612	0.590	0.571 - 0.614
6.00p.m.	0.397	0.417	0.387	0.375 - 0.432

SOURCE: DERIVED FROM FIELD DATA

radiation in the night, thereby, making the night temperature higher than what it is in the rural environment.

Table 2 shows the average seasonal net radiation over the tarred road surface in Aba town.

From Table 2, there was a steady increase in the net radiation from morning till afterncon as a result of increased insolation accompanying the length of the day. By the early afternoon there was a sharp increase in the value of the net radiation especially during the dry season and in the evening there was a steady decline of the net radiation which was suspected to continue into the night with the early part of the night being hotter than the very early morning hours. This is the mechanism which is responsible for the urban heat island effect in any urban environment. The net radiation over the tarred road surface in Aba, is therefore higher (Fig. 2). The major reasons for this could be. due to the low albedo associated with dark colored surfaces (Adebayo, 1990; Sellers and Robinson, 1986; Oguntoyinbo, 1979; Hare and Sweeny 1986). Secondly, the tarred road surfaces are rather rough which also reduce albedo therefore leaving the net balance on the high side. The hard nature of the surface is also a factor as it eas-

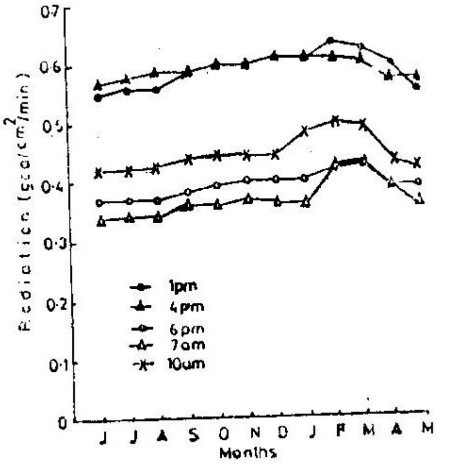

Fig. 2: Average monthly net radiation over tarred road at Aba (1993 - 1994).

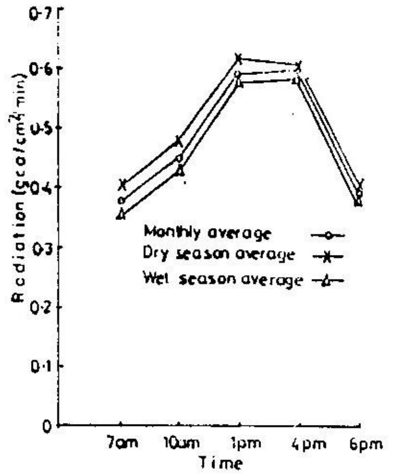

Fig. 2b : Average seasonal net radiation over tarred road in Aba

ily reaches its maximum heat retention level excluding the rest of the radiation incident on it.

IMPLICATION

The proportion of tarred road surface has been on the increase in almost every urban center including Aba and efforts are even geared towards making every streets in most urban centres tarred. This has serious implication to the urban energetics. The high radiation balance over the tarred road surface invariably means that the surplus energy stored up in this surface will be used to heat the air in the urban center during the day and night leaving the urban temperatures higher than the surrounding environment. This has serious consequences as this will act as a feed back on to the urban structures like concretes walls roofs, walk ways etc; which are also stores, resulting in a small initial increase in temperature becoming more pronounce temperature island in the urban center. The consequences on man, animal, structure and even things cannot be underestimated. This is what is responsible for the excessive heat experienced in the urban environment of Aba for a greater part of the twenty four hours. Human comforts level is reduced and the discomfort index increases especially under humid conditions.

These conditions can be checked by intensive tree planting in all areas and especially along the side of roads. These plants will act, not only as shed trees, reducing the impact of the direct insolation on the road surface, but also as a means of expending the excess heat through the process of evapo-transpiration. Also, "green belts", and recreational areas should be created, where there is intensive vegetation, within the urban areas. Presently, constituted, the centres have higher temperature than the rural environments (Adebayo, 1985;Chandle, 1970; Griffith, 1976; Smith, 1975; Jaurequi, 1984). Efforts therefore should be geared towards reducing the urban temperature rather than increase it.

CONCLUSION

Though urban zones differ in their albedo from their rural surroundings, the heat capacity of the tarred road surfaces is very high compared to soil and vegetation surfaces (Ekanem 1997). This is because it is very efficient at absorbing and storing heat received during the day time, and later when this heat is release (especially after sunset) to the air, it cushions the fall of nocturnal temperatures and therefore enhances the thermal contrast between urban and rural areas. As a result of more efficient drainage system and a generally impervious surfaces, urban environment are becoming much more drier than adjacent vegetation and soil surfaces. This means that much more of the available net radiation is used in heating the urban atmosphere directly than in evaporating moisture. When moisture is evaporated, latent energy is used which does not result in direct air temperature change. The warming effect caused by the direct heating of the urban surfaces and the little or no evaporation over dry city surfaces is the main cause for the increase temperature regime of the urban centres.

Therefore, the need of leaving untarred, vegetated surfaces within the urban center is emphasized, as this will increase the rate of evapo-transpiration and subsequent cooling of the air temperatures.

REFERENCES

Adebayo, Y. R., 1985. The Microclimatic Characteristics within the urban canopy of Ibadan. Ph.D Thesis University of Ibadan (unpublished).

Adebayo Y. R., 1990. Aspects of the variation in some characteristics of Radiation Budgets within the urban canopy of Ibadan Atmospheric Environments 24 B (1): 9-17.

Chandler, T. J., 1970. Urban Climatology Summary and Conclusion of the Symposium in urban climates. WMO Tech. Notes No. 108 Geneva: 375 - 379.

Ekanem, E. M., 1997. The urban surface Energy Balance in a Humid Tropical City of Aba: Ph.D Thesis. University of Ibadan (unpublished).

Griffiths, J. F. 1976. Applied /Climatology: An Introduction (2nd ed.) Oxford University Press. London, 136 pp.

Hare, G. O. and Sweeney, J., 1986. The Atmospheric System: An Introduction to Meteorology and Climatology. Oliver and Boyd. Edinburgh. 208 pp.

Jaurequi, E. 1984. Tropical Urban Climates: Review and Assessment W.M. O. Tech. Conf. On Urban Climatology and its application with special regards to tropical areas. Mexico: 26 - 45.

Mabogunje, A. I., 1978. Towards an urban policy in Nigeria, In Sada P. and Oguntoyinbo J. S. (eds). Urbanization processes and problems in Nigeria. Ibadan University Press. 7 - 20.

Ofomata, G E. K., 1975. Relief in Ofomata G. E. K. (ed) Nigeria in Maps: Eastern States. Ethiope Publishing House, Benin City: 8 - 9.

Oguntoyinbo, J. S., 1979. An Albedo Map of Nigeria Nigeria Geographical Journal 22 (2): 185 - 191.

Sellers, A. H. and Robinson, P. I., 1986. Contemporary Climatology. Longmans and John Wiley, New York 439 pp.

Smith, K., 1975. Principles of Applied Climatology McGraw-Hill Books Company, UK. 233 pp.