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SOME ASPECTS OF URBAN CLIMATOLOGY OF VISAKHAPATNAM

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ABSTRACT : Urban climate may be defined as the climate that is generated and modified by the various components of an urban agglomeration. Urban and non-urban environments, with their inherent physical and cultural characteristics exert a strong influence on the prevailing climate, particularly with regard to its thermal structure.

While climates of urban and rural areas have their own basic distinguishing features, different sub-environments within the urban complex, exhibit peculiar climatic regimes depending upon their characteristic differences like built-up areas, roads, building materials, population density etc.

Visakhapatnam, with sea on the east and hill ranges on the north and the south and varied surface configuration, is selected for the present study for examining the variations in thermal climate as determined by its various urban peculiarities. Such environmental factors as proximity to the sea, extent of paved surfaces, nature of super-structures, building materials used for housing, compactness of dwellings, density of population, traffic nodes, city cores etc. have an extremely strong role to play in this context. The manner in which these peculiarities interact and influence the urban climate is analysed in detail in the paper.

The study is based on the surface air temperature surveys in Visakhapatnam conducted for six continuous years during the winter seasons from November to February every year from 1974 to 1979. The temperature data are reduced to a common time reference, to render them mutually comparable. Data, so reduced is plotted on large scale maps of Visakhapatnam and interpolated to obtain isotherms of various values; patterns of isotherms are compared internally and externally and the findings are summarized.

It has been known for quite a long time that cities not only modify the prevailing climate but even generate their own characteristic climates. In an urban agglomeration construction of houses, roads or factories disturbs the existing microclimates and may generate new ones of great complexity depending on their design, density and dimensions. By urban climate is meant the net meteorological result of the structure and size of the city in their interaction with the physical variables, of the urban atmosphere like temperature, amount of water vapour in the air, speed of the wind, the amount of solar radiation and the amount of precipitation.

Very often the city itself is the cause of these differences. Its compact mass of buildings and pavements obviously constitute a profound alteration of the natural landscape and the activities of its inhabitants are a considerable source of heat. Together, these factors account for five basic influences that set the urban climate apart from its non-urban counterpart (Lowry, 1967).

The first influence is the difference between surface materials in the city and in the countryside. The predominantly massive rocklike materials of the city's buildings and other structures as well as streets can conduct heat about three times as fast as it is conducted by the wet, sandy soil of the rural setting. Second, the city's structures have a far greater variety of shapes and orientations than the features of the natural landscape. The walls, roofs and streets of a city function like a maze of reflectors, absorbing some of the energy they receive and directing much of the rest to other absorbing surfaces. Third, the city is a prodigious generator of heat, particularly in winter when the various heating systems are in almost continuos operation. Even in summer, too, the city has many sources of heat generation, among them are factories, vehicles and even air-conditioners which must pump out hot air in order to produce their cooling effect. In the cities, precipitation water is quickly removed from the surface through the well-engineered drainage systems whereas in the country much rain water stagnates on the surface. Thus, in the countryside, either free water on the surface or that which has infiltrated into the soil is available for evaporation, which is of course a cooling process powered by heat energy. Because there is less opportunity for evaporation in the city, the heat energy that would have gone into the process is utilized for heating the air. Finally, the air in the city is different in that it carries a heavy load of solid, liquid and gaseous contaminants.

Each city has its own individuality and thereby has its own special climate. hence it is difficult to infer the climate of all cities by generalizing from observations within one or a few cities. Yet, it seems eminently clear that cities are warmer, cloudier, rainier, less sunny and less humid than the surrounding countryside.

The growth of industrialization changes the city climates to a cousiderable extent, by injecting materials and heat into the atmosphere. The city atmosphere is therefore, liable to pollution, particularly as a result of combustion of oils and fuels, by smoke, dust, sulphurdioxide and other gases. Automobile is another important source of air pollution. Surface transportation of people and goods may contribute to the modification of city climate in two ways : first by the emission of particulate and gaseous exhaust products from motor vehicles into the atmosphere and second by the modification of the reflective and thermal properties of the land surface by highways.

The thermal characteristics of areas are in marked contrast to those of the surrounding countryside, It is common experience that the central parts of cities are warmer (for the various reasons already stated) than the surrounding suburban areas particularly at night, a phenomenon often referred to as the "urban heat island." The study of urban heat islands and low level atmospheric stability is very important in city planning for the avoidance of possible air pollution hazards. When the temperature decreases sharply with height considerable mixing can occur in the atmosphere and any air pollutant will be dispersed rapidly. When an increase of air temperature with height prevails at lower levels of the atmosphere - a condition known otherwise as "temperature inversion" – air tends to stagnate and become "stable." Under stable conditions, pollutants in the air do not get dispersed and and this in turn gives rise to problem of air pollution hazard. It is during the cool weather season when low level temperature inversions are frequent and intense that air pollution incidents too are common. Broadly, the inversions at

Visakhapatnam appear on about 50% of the days during the winter season of the four months namely, November, December, January and February (Subrahmaynam & Sastry, 1976). The month of December is associated with maximum number of inversions, closely followed by February, January and November in that order.

Structure and Thermal Nature of Urban Heat Islands

Urban agglomerations because of the massive masonary buildings and congestion generate their own peculiar climates different from those of the surrounding countryside. Of the many meteorological parameters that are affected by urbanization, temperature anomalies are well known and widely reported. One of the most noticeable climatic characteristics of cities is their excessive warmth compared with their surrounding suburban and rural areas. The location, shape, size and strength of heat islands is generally controlled by the physical dimensions and structural properties of the built-up area as well as by the meso-scale weather patterns. Higher thermal capacity of the city structures and pavements; power generation, transportation, and reduced wind-speed due to the tall and uneven city structures are accepted causes for the

Fig.1

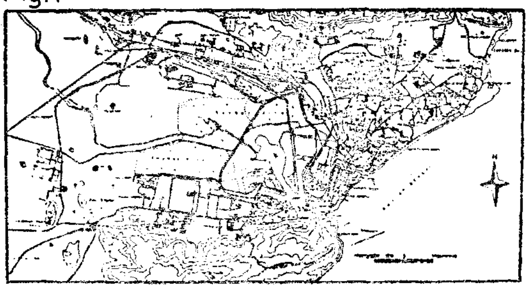


Fig 2 Dec.74

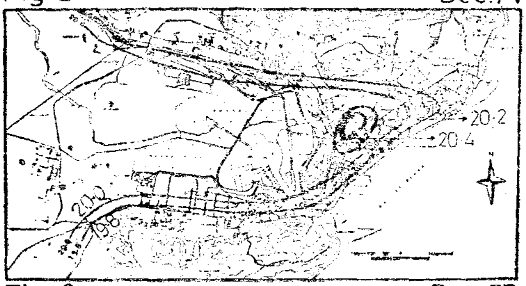


Fig 3 Dec 75

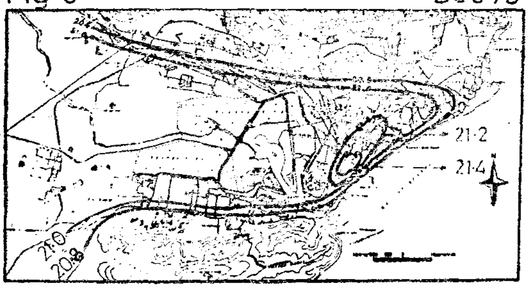


Fig 4 Dec.76

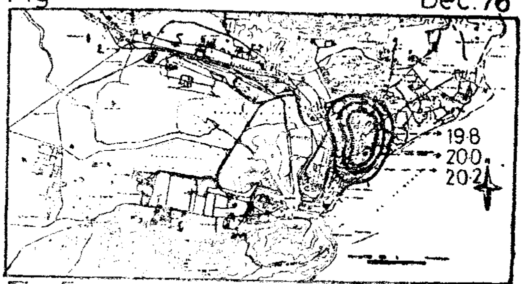


Fig 5 Dec.77

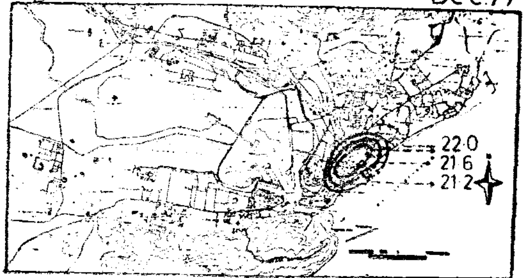
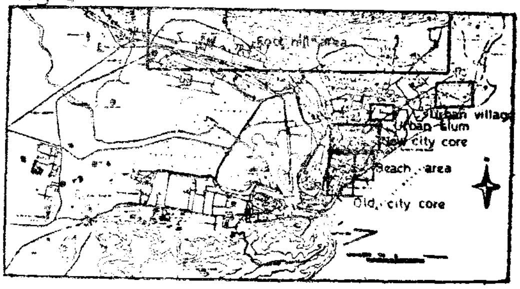


Fig 6



Figures 2,3,4,& 5,:Surface Temperature Distribution.
Figure 6,: Representative Environments.

formation of heat islands. These heat islands which result from the combined action of the several factors mentioned above vary in size and intensity from city to city and in the same city from season to season. Lands berg (1962) Chandler (1965), Oke (1973), Padmanabha Murthy and Hirt (1974) and several others documented heat islands intensities under diverse meteoroloical conditions and geographical locations.

Heat island is not an instantaneous phenomenon but develops progressively after sunset. It adds to the development and self-sustenance of what is called a "dust-dome" and a "haze-hood" of contaminating particles floating in the atmosphere. It also helps in the setting up of a recirculation of air pollutants thus making the pollution problems more serious. The study of heat islands is very important in city planning for the avoidance of possible air pollution hazarads.

Visakhapatnam (Fig. 1) is a rapidly growing urban town situated on the Bay of Bengal coast of South India between two east-west hill ranges of the Eastern Ghats-the "Kailasa" range on the north and the "Yarada" range on the south. The Bay of Bengal forms the eastern boundrry of the town with a coast-line about 10 Kms, in length running northeast to soutewest. The western side is an extensive tidal basin, a major portion of which is being slowly reclaimed. It can thus be described as a V-shaped town. Between two dominant hill-ranges and with a vast expanse of low-lands and a number of scattered hillocks the landscape presents a rugged appearance. Its natural local climate owes its origin to the peculiar topography, on the north and the south and the vast oceanic water body on the east contributing to the land and sea breeze circulations in different seasons.

Begun as a fishing villag Visakhapatnam gradually developed as the district headquarters, as a railway junction and thence as a port-town. It has today grown into an ugly urban agglomeration with about seven lakhs of people. The city is rapidly becoming industrialized bringing in its wake several environmental problems. The main industrial belt extends to Gajuvaka on the north-western side of the Yarada hill range.

The residential area of the town has a horse-shoe shape with the southern part heavily over-crowed having congested houses, high population density and poor urban amenities. The northern part on the otherhand is rather sparsely populated with haphazard growth mainly on account of topographical diversties. The slums of the town, more than 70 in number, are distributed in such a way that no part of the town is fully free from them. These slums are over-crowded with thatched huts, narrow and unpaved streets, inadequate and improper sanitary arrangements. The heaviest crowding of houses and highest population density are noticed on the Old Town areas.

The unique geographical setting of Visakhapatnam with the Kailasa hill range on the north, Yarada range on the south and the Bay of Bengal on the east complicates the problem of disposal of domestic and industrial pollutants. The trend towards urbanization and industrial concentration has resulted in severe and widespread environmental contamination, especially of the atmosphere. The location of all major industries on the southern and the southwestern sides of the residential colonies requires a serious re-examination as the gas effluents of these industries are carried by the southwestern prevailing winds over the residential areas in the north and the north east.

The main aim of the investigation reported in the paper was to indentify heat islands in the Visakhapatnam urban complex and to study their thermal structure. Such information will be very useful in understanding the basic aspects of atmospheric pollution at Visakhapatnam especially from the point of view of imbalances in the dispersion of air pollutants in the lower atmosphere. For studying the surface air temperatures and identifying urban heat islands, a detailed survey programme was undertaken at Visakhapatnam during the winter months (November to February) from 1974 to 1979.

Survey Programme

To facilitate the coverage of representative section in the whole city some 12 traverses have been laid, each traverse covering about 10 to 15 pre-selected representative spots it the different sections of the city. The various traverses and the points were so chosen as to ensure adequate coverage of the main urban area and parts of the suburbs. The observational period was as it should be, near the minimum temperature epoch when the heat island effects are known to be the most prominent. Days with clear skies and calm winds were selected as far as possible. On each day of observation the survey was started from a suitable terminal point on a particular traverse. At each point point dry bulb and wet bulb temperatures observations were taken at a height of 1.5 metres above the ground with a standardized Assman Psychrometer and the exact times of observation noted for each location. After all the points of the traverse were covered, a repeat observation was taken at the starting point, thus completing the observational circuit. In order to obtain actual temperatures corrected for normal variation during the period of survey bimetallic tharmographs were run at representative locations from the previous night and the observations at each point were reduced to a common time-base by applying a correction for the time trend of temperature during the period of observations. The so adjusted temperatures were then plotted on a large scale map of the city section and isotherms drawn taking topography also into account. The survey programmes were conducted periodically and the temperature data for Visakhapatnam were obtained on representative days during winter season for six years from 1974 to 1979.

Results and Interpretation

The survey programme was started during the winter period of 1974. Fig. 1 shows the Industrial-urban complex of Visakhapatnam city, The surface temperature distribution in the city during December 1974 is shown in Figure 2. Though the isotherms generally tend to run parallel to the coast line the cores of high temperature zones are located at built-up and congested areas. Warm zone is found over the city core, but the temperature difference between the periphery and the central areas is not much. Figure 3 for December 1975also shows the same trend of isotherms running parallel to the coastline but, as before higher temperatures are concentrated in the old town area. The " Old Town " area, as stated above, is the most congested place in the town with clustered buildings and high population density, and is also a very busy commercial centre. With all these urban activities, therefore, it is a warm zone with higher temperatures over the surrounding areas but the temperature difference between the outer region and the core is only about 1°C.

During the earlier (1974 and 1975) surveys of the entire Visakhapatnam city heat islands were invariably found over the congested and closely built-up areas. As such the subsequent surveys were conducted only in and around built-up areas with a view to obtain the thermal structures of heat islands associated with them. Figure 4 shows the temperature distribution during December 1976. Though the actual temperatures were much lower than those for the previous two Decembers (i. e. 1974 and 1975). the temperature difference between the outer and inner areas again was somewhat low. In December 1977 (Fig. 5) there was a general rise in surface temperatures to almost the same level as in December 1975.

Visakhapatnam exhibits typical environments, such as the coastal zone, foot-hills, urban slum, urban village, old city core and city core. In order to study the interaction

Fig.7

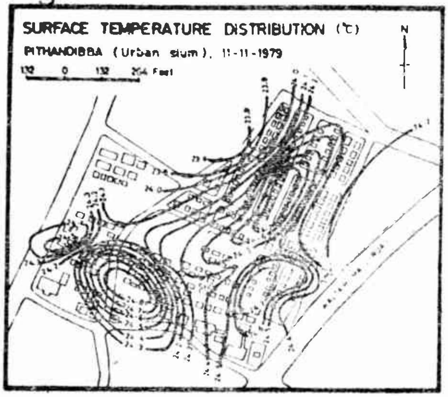


Fig.10

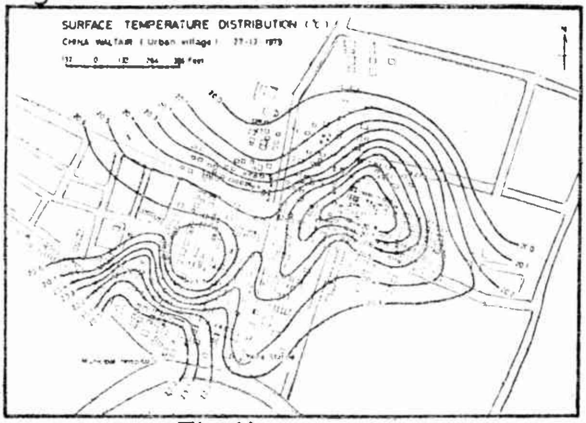


Fig.11

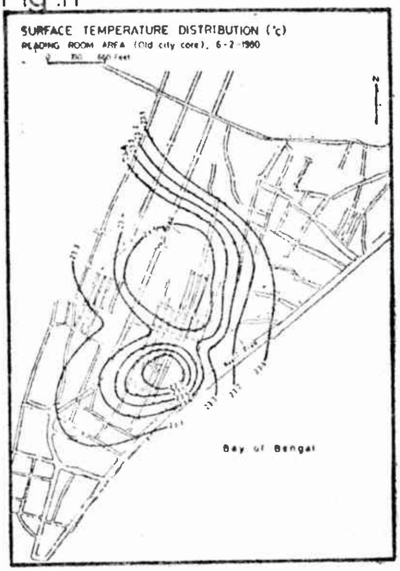


Fig.8

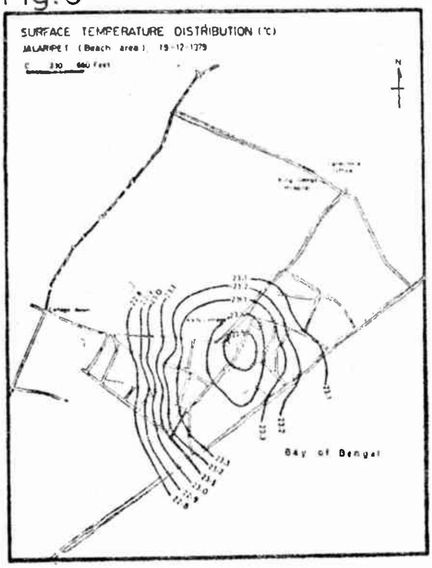


Fig.12

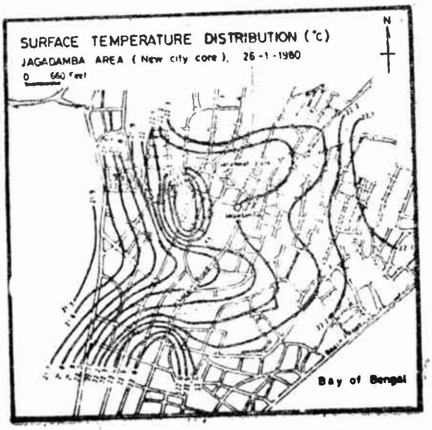
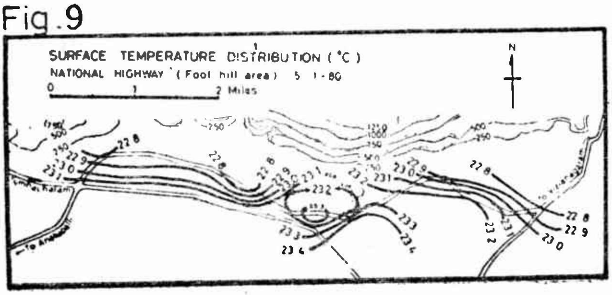


Fig.9



of those environments on the thermal climate of the city, six representative areas have been selected (Fig. 6) and surveyed as explained before during the winter season of 1979. These six areas have their own typical physical or cultural (or both) backgrounds and significant environment of which each area is representative is given in the table below :

Table- I

Six Representative Environments in Visakhapatnam

Area	Representative environment
Pithandibba	Urban slum
Jalaripet	Coastal
Fational Highway 5	Foot-hill
China Waltair	Urban village
Jagadamba area	City core (New town)
Reading room	City core (Old Town)

Temperature surveys were made in the above-mentioned areas on six representative dates viz., 11.11. '79, 19.12. '79, 27.12. '79, 5 1. '80, 26.1. '80 and 6.2. '80 and Figs. 7 to 12 show the corresponding isothermal patterns.

Pithandibba - urban slum

It is located between two main thoroughfares of the city-Waltair main road and the Jail road. The isothermal pattern in the Pithandibba area (Fig. 7) is seen to bear close resemblance to the dwelling concentration in the slum. Two intensive heat islands come out conspicuously here with their central cores over the central parts of the slum dwellings. The temperature difference between the outer regions and the cores was about 1°C but the horizontal temprature gradient ranged from 0.4°C to 0.8°C per 100 feet depending upon the physical features of the different settings of the slum.

Jalaripet - coastal environment

'Jalaripet' is another typical fishermen slum situated right on the beach. As regards the types and distribution of houses and population density it resembles very much the interior Pithandibba slum. Examination of surface temperature profiles presented in Fig. 8 for the area reveals that the core of the slum, despite its openness on three sides, still maintains a heat island though of a weaker nature. The minimum temperature recorded during the survey was 22.8°C which is a good illustration of the influence of sea on the thermal behaviour of slum, other factors remaining the same.

National Highway No. 5 - Foot-hill environment

This is another typical case, namely a foot-hill environment which is a 9.6 kms. stretch of National Highway (No. 5) road from Maddilapalem cross road to Gopalapatnam cross road. Strictly speaking this is not a single concentrated slum but has a number of small clusters of hutments and hamlets scattered on either side of the highway without any slum core as such. The main idea in selecting the area was to study the level of interaction as revealed through air temperatures between the foot hills and the linearly distributed slum clusters along the highway. Surface temperature distribution in this area is presented in Fig. No. 9. The hill-ward side temperatures are relatively lower (22.8°C) than the other side (23.4°C) with a variation of 0.6°C across the highway. No strong heat island as such is noticed here for the reason that the area doesn't have dense clusters of slum dwelings. Lower temperatures, along the hillward side may be due to the draining of cool air from the altitude to foothills and also due to the vegetation around.

China Waltair — urban village

China Waltair was originally a village. During the process of urban spread of Visakhapatnam, this village too has become somewhat urbanized. The distribution of surface temperatures during the survey in this environment is clearly illustrated in Fig. 10. The size, shape and intensity of the heat islands seem to coincide very closely with the size shape and structure of the slums. Since the village is enclosed by and at the same time quite insulated from the urban influences of the well and sparsely developed colonies all around, the generation of higher temperatures is restricted only to the thickly populated areas of the village. The difference between the highest and the lowest temperatures is 0.8°C with a gradient of 0·3°C rise per 30·5 metres of linear distance into the interior. The village can be regarded as a typical example in city climate studies to illustrate how a thickly populated slum is free to play its role in influencing the surface temperature distribution.

City Cores – old town and new town

While the old town area is the hard core of Visakhapatnam city that has not much altered in its nature, the Jagadamba area is the new core which resembles any other metropolis in the country. Since both of them represent the city cores (CBDs) and have similar characteristics in many respects, the discussion is made simultaneously. The "old town" area is the most congested place in the town with tall narrow and clustered buildings, narrow streets and high population density and is aiso a very busy commercial centre. Consequently it exhibits higher temperatures compared te the other areas. It can be seen from Fig. 11 that the zones of high temeratures in the old township are located over the built-up and congested areas like the Town Hall and the Reading Room, the temperature variation from the core to the periphery being from 23.7°C to 23.1°C. On the other hand, in the core of the new town area the heat island envelops the Suryabagh market area and the college-down area (Fig.12). The temperatures here vary from 22·6°C in the core to 21·5°C to the periphery registering a total difference of 1·1°C. Both the city cores exhibit heat islands of a well-developed nature due to the fact that the building complexes are massive and also because most of the surface is covered with heavy concrete and asphalted materials which absorb heat energy during day-time and emit out during nights.

Conclusions and Recommendations

The surfacet emperature surveys conducted in Visakhaptnam over a period of six years from 1974-1979 reveal the following facts.

(1) Viewing the full thermal profile of the entire city, high temperatures concentrate over areas of super-concrete structures and greater surface coverages with asphalt materials.

(2) At the micro level, the studies indicate that compactness of the dwellings with thick population density normally produces and maintains high temperatures than the surroundings registering steep thermal gradients. On the other hand, thinly-dwelled super-structures with low population density exhibit relatively low variation of temperatures with gentle thermal gradients.

(3) Heat island occurrence follows closely the patterns of surface topography both natural and man-made.

(4) Heat island phenomena are not restricted to single locations but are complicated zones with multiple cores corresponding to the nature and distributions of city structures (Padmanabha Murthy, et. al, 1973).

(5) Heat islands are dynamic in character in that their intensification of dissipation is not an abrupt but a continuous process.

It is more often observed that cities experience their own peculiar local climates than the original natural climate uninfluenced by the urban characteristics.

To obviate the heat island effects increasing air pollution and stagnation in metropolitan areas, Padmanabha Murthy (1980) suggests that individual dwelling houses should be surrounded by greeneries rather than the city having interspersed blocks and parks in isolated locations. For abatement of air pollution problems a thorough understanding of city climates is necessary. Since each city is unique in its own way, no universal model can be suggested for urban planning. More basic work is needed in urban meteorology before specific recommendations can be made with regard to the siting of residential colonies and industrial units.

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