CYCLONES, STORM SURGES AND THE ENVIRONMENT

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Tropical cyclones are storms with winds of over about 120 kph (or about 73 mph). Many can have sustained speeds of 200 kph (120 mph) and gusts upto 400 kph (240 mph). The word " cyclone " is derived from the Greek " Kyklos" for the coil of a snake.

Similar meteorological phenomena are called by other names in different parts of the world. In the Western Hemisphere regions of the Caribbean and North Atlantic they are known as "hurricanes" (from Huracan, the name of a Carib god of evil) while the term "typhoon" is applied to those forming in the Pacific.

The biggest of these storms are those of the Western Pacific. Other names applied to these storms are baguios near the Philippines, papagallos in the eastern North Pacific, trovadoes around Madagascar and willy - willies by Australia.

The approximately 80 to 100 tropical cyclones each year mostly arise between about 5 and 30 degrees on each side of the equator. However, "Arctic cyclones" are also known, although the conditions leading to their formation are somewhat different from those resulting in tropical cyclones.

Associated with cyclonic storms are the storm surges or coastal floods of meterological origin. These have also been called tidal waves but the latter term has also been used in connection with the tides related to the gravitational attraction of (principally) the sun and moon as well as for seismic sea waves (or "tsunamis"). The latter are usually a result of under sea vertical land movements, as in earthquakes, but also by other geological events, such as volcanic eruptions.

The greatest damage caused by a cyclone is usually attributable to that caused by the storm surge and the flooding which takes place on land. Since these are closely interrelated it is of interest to examine how they arise and develop.

Origins and development

A. Tropical Cyclones: A Tropical cyclone may commence after moist air is warmed by the sun and rises upward from a warm sea. On reaching a certain height the moisture condenses into droplets of water. This condensation results in the release of energy which warms the surrounding air - thus providing further force to its upward movement.

The reduction of atmospheric pressure which results causes more moist air to rush in. In the cases of storms which become cyclones north of the equator, the earth's rotation causes the air to take an anti-clockwise movement.

In the case of cyclones south of the equator, a clockwise movement takes place. The centrifugal force caused by the spinning wind system tends to expel air and cause a drop in pressure within.

The spiral of winds, thus, has at its center an "eye" or region of calm with only light rain. This eye may often be only a few kilometres in diameter. The actual cyclone could, however, be one to two hundred kilometres across with a height of around eleven to nineteen kilometres. The effective region of disturbance could reach upto 500 km in diameter.

The cyclone may move at around 15 to 30 kph over tropical seas and over thrice these speeds at other latitudes before exhausting itself. Over land it exhausts itself more rapidly but the rainfall shed by it usually causes serious floods and loss of life.

B. Artic cyclones: Artic cyclones are different from tropical cyclones in several characteristics. For instance, a) the diameter of the storm may be much more compact although that of the 'eye' may be more similar, b) they may develop in under 24 hours rather than taking up to around a week, c) they are most frequent from October to April, d) their height may be only around 8 Kilometres and, e) While their speed of travel may be twice that of a tropical cyclone the wind speed may be only 80 to 160 kph.

Their identification as being cyclones has been confirmed by satellite photographs using infra red cameras.

C. Storm surges: Storm surges may sometimes account for upto ninety percent of the casualties of the impact of a cyclone. They are most prevalent along coasts of the Bay of Bengal, the Gulf of Mexico, the eastern seaboard of the USA, Japan and some other Western Pacific Islands. Some coastal areas of the North Sea may also be affected.

Storm surges are however, mostly associated with tropical cyclones. Two factors contribute to their

Coastal errosion due to destroying mangroves for timber.

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generation. The first is the drop in atmospheric pressure which causes the sea water below to be raised by a small amount.

The other factor is the effect of the strong wind component along the surface of the water. The height of the surge depends partly on the strength of the wind and may reach over 25 feet and last for some hours.

Some of the factors which can modify a storm surge are, a) the cyclone characteristics, b) the depth of the water, c) the shape of a bay, d) low-lying islands, e) the normal tide action and f) inlets and estuaries.

Depending on the drainage area of a river, the flood and storm surge associated with a cyclone may occur together or separately. In the case of a river with a large drainage area the two may be quite distinct while in that with a small drainage area, the two may occur together. In intermediate cases (eg. of drainage area between 1000 and 3000 sq. km.) the two could meet partway up the river.

D. Requirements for formation of a cyclone: Several factors have been described as being necessary for cyclone formation. However, it has also been noted that such factors or conditions are frequently present in tropical oceans without cyclones necessarily developing. work therefore needs to be done to establish definitively why cyclones are relatively rare even when conditions are apparently suitable for their formation.

An important condition for the development of a tropical cyclone appears to be a column of water of a depth of 60 metres or more at a temperature of 26 centigrade or more.

The temperature difference between the surface water and the atmosphere should be sufficient to ensure the smooth rise of warm moist air while the depth of the column appears likely to be necessary for the prevention of mixing with cold water from the lower strata.

Coral reefs are being mined to manufacture lime.

Other requirements appear to include minimal vertical wind shear through the tropospheric layer and that the coriolis parameter should not be below a minimum figure. However as stated above, even when these and other described empirical conditions are met, tropical cyclones do not necessarily occur.

Arctic cyclones which may reach the intensity of those of the tropics arise, as mentioned earlier, under somewhat different conditions. Here the conditions for them to develop appear to be met by the great differences in temperatures between the seas and the atmosphere above.

For instance, the ocean currents may have temperatures as much as around 18 centigrade, while that of the air cooled down by the polar ice may have fallen down to around -29^0 centigrade. While other factors, such as the earth's rotational force, have influences on artic cyclones different from those occurring in the tropics, the answers to many of the questions relating to them may lie in the interactive effects of relatively warm ocean currents and warm and cold air currents above.

E. Cyclones in the Bay of Bengal: Our main interest, however, is in the destructive cyclones that occur in the Bay of Bengal. These are most frequent in the pre-monsoonal period of April-May and the post-monsoonal period of September/ October to December. Violent cyclones have not generally been a significant problem from January to March while the phenomena that occur during the southwest monsoon of June to September have been rather classed as being monsoonal depressions.

Among the numerous records of violent cyclones in the Bay of Bengal are:

a) that of the furious hurricane (together with a violent earthquake) which took place on October 7, 1737 at the estuary of the Ganges causing 300,000 deaths.

b) that on the Coromandel coast on April 13, 1749,

c) that in November 1797 in the northern part of the Bay and

d) that between Trincomalee and Madras around December 4, 1803. Records of violent cyclones occurring in the Bay of Bengal and affecting littoral states exist from those years to the present.

Anwar Ali has noted that 25% of the 19 most severe cyclones disasters experienced in the world in 1960 to 1970 affected Bangladesh. That of 12 November 1970 led to some 500,000. deaths and $ 63 million crop loss in addition to other severe losses and damage.

Other cyclone disasters to have affected Bangladesh include those of

1822,1876 and 1897 causing 40,000, 100,000 and 175,000 deaths respectively. Flooding of the plains are a primary cause of the terrible tragedies wrought by cyclones to this region.

The environmental aspects

Considerable damage is caused by tropical cyclones and the associated storm surges. The damage can include short-,medium-and long-term effects and it could affect natural physical features and living organisms, as well as human life and activities. These aspects are, however, interrelated and it is not practical to discuss them under defined headings. However, mention could be made initially of factors which may modify the damaging effects of cyclones and storm surges.

First, it will be recalled that one of the factors predisposing to the development of a tropical cyclone is a temperature of at least 26^0 centigrade from the surface to a depth of 60 metres or more. While the influence of other factors are necessary to ensure or "kick" the development of a tropical cyclone, it has been suggested that if the hypothesized global warming due to the "greenhouse effect" does occur it may well lead to the increased frequency of violent cyclones.

This hazard would be in addition to the possibility of inundation of low-lying land and islands should the levels of the ocean rise due, at least in part, to the melting of some of the polar ice caps.

Secondly, mention should be made that some protection against cyclone -related damage is afforded by the living natural barriers of coral reefs and trees. These could be included among the first lines of defence, particularly when the trees include belts of mangroves.

However, unfortunately coral reefs are being mined to manufacture lime for construction purposes while the mangroves are being felled for timber and other purposes. Similarly, coastal marshes which provided a valuable "sink" for flood waters are often filled in for housing developments (which may be exposed and in the path of an advancing storm).

Some of the many factors which can modify a storm surge have been given earlier. Once a cyclonic storm moves onto dry land it may exhaust itself fairly soon, particularly when it expends its energy against obstructions such as mountain ranges, hills and inselbergs.

The damage which is, however caused by cyclones and storm surges on land can be considerable and, as has been noted above, include damage to structures and living organisms and disruption of human life and activities. It may also, however, be said that not all effects are damaging but that a few may in fact be beneficial.

One cyclone in Sri Lanka, for instance, washed away some long-standing pollution from a pulp and paper factory on the east coast and also increased the salinity of some lagoons to the benefit of the breeding of prawns and crabs.

However, the most widespread effects of tropical cyclones and their storm surges in the loss of life and extreme property damage they cause . We shall next consider some of these questions although the discussion cannot claim to be comprehensive of all the problems which may arise.

For instance, the economic cost to a nation of diverting funds, administrators and technologists during the period of reconstruction will not be discussed nor, for example, the possible environmental consequences of a nuclear power plant being damaged by a severe cyclonic storm.

One of the earliest effects of a cyclone may be on fishing boats out at sea. Loss of life and destruction of fishing vessels, whether out at sea or on inland waters has been a feature of many cyclones, whether in the tropics or in Arctic waters. For instance, around 9000 marine fishing boats and 90,000 inland water fishing boats were lost in the Bangladesh cyclone on 12 November 1970.

When approaching land the cyclone (ie. together with its storm surge) may change the topography of the sea bed and change the pattern of waves and currents. Next loose sand may be pushed up the beach and later drawn back, together with sediment and topsoil, into the sea.

If there is reef of live coral in the area the particulate matter may be deposited in the pores and cause the death of the coral animalcules. The death and eventual degradation of the reef would leave the beach and coast more exposed to subsequent wave action and erosion.

The destruction of the coral reef would also lead to that of a complete specialised ecosystem. The coral reef habitat, as is well known, supports a large number of fish and other living organisms, such as anemones, which are directly or indirectly, interdependent on each other.

The export of ornamental aquarium fish and shellfish taken from the coral reef habitat is as well, a useful earner of foreign exchange for some of the countries of the region in addition to the attraction of coral reefs for tourism. These too may be affected in the aftermath of a cyclone.

The movement of the cyclone onto land causes widespread uprooting of trees and other vegetation. If a belt of mangroves is present, they will reduce some of the force of the cyclone and storm surge. However, it must be recognised that the mangrove habitat is a location of choice for the breeding of fish, shellfish and other aquatic organisms in addition to supporting populations of amphibians, reptiles and birds. The passage of a cyclone through such a specialised habitat inevitably wreaks havoc on the communities it harbours as well as, eventually, on the adult forms which spent their larval or juvenile stages in mangrove areas but later migrated elsewhere.

Similar considerations apply following the passage of a cyclone through other specialised habitats such as seagrass beds.

The cyclone which hit the east coast of Sri Lanka near Batticaloa on 24 November 1978 caused the destruction of a large number of coconut palms (and an additional hazard was caused due to the blowing of debris such as coconut husks found abundantly on such plantations.)

Other crops, such as rice, may also be affected during a cyclone. The damage to crops may be physical due to the wind. However, additional degradation or agricultural land may be caused by movement of topsoil (sometimes into the sea) and due to salinization of soil and ground water due to passage of the storm surge.

The salt and the soil may get washed out by the heavy rain deposited during the monsoon. However, in some cases, additional leaching with fresh water may be necessary.

The salinization of wells and surface water may present a problem in obtaining adequate drinking water supplies for people and animals immediately after a cyclone. This is indeed a major factor in the widespread destruction of surviving wildlife, animal and plant, immediately after a cyclone.

Related problems of starvation and disease occur among wild animals, livestock and people following a cyclone.

The maintenance of population of wild animals takes on lower priority, particularly when the numbers of people and livestock affected are of any significance.

In addition to the question of availability of resources at short notice, the provision of emergency relief is hampered by the damage to hospitals, Water supply schemes, roads, railways and telecommunications and disruption of community services. In cases of widespread damage, it may be of a higher priority to replant rice crops than to attempt to set about reconstruction of houses, schools and other buildings.

Outbreak of looting and theft is another social environmental problem which may occur under these conditions.

Pre-storm policies

Considerable work has been done worldwide regarding policies and procedures in relation to coping with natural disasters. It is not proposed to discuss in any detail the work of relevance to cyclones and storm surges here, but a fairly quick review of some principal noteworthy points may be helpful in connection with certain environmental questions and preliminary to the later discussion.

One of the first pre-requisites to coping with cyclones and storm surges is to identify the cyclone-prone areas and list the problems which may occur.

Some problems which may arise may be serious enough to justify the preparation of a special contingency plan to follow should an unlikely event take place. An example could be serious damage being caused to nuclear power installation.

An estimation of whether an area is cyclone-prone would initially require an examination of historical records of cyclones and storm surges in the region and available meteorological data. However, this can, at best only help to assess the probability of a cyclone of "typical" severity affecting

the area at a given frequency.. In addition, it cannot exclude the possibility of occurrence of a cyclone of unusual severity.

Again, the available data may be inadequate to prepare more than general estimation of maximum wind velocities which could be experienced. This would be relevant to arriving at building design and construction criteria keeping in mind the reasonable use of available resources. It must, also, be noted that the estimates and decisions based on these would need to be reviewed regularly as an ongoing process.

Even the risk assessments themselves may change over time, for example, if, as mentioned above, global warming due to the "greenhouse effect" proves to influence the frequency and characteristics of tropical cyclones.

With the help of orbiting satellites and cloud imagery, the task of accurately locating the centre of the cyclone is much facilitated.

However, predicting a cyclone's future path poses greater problems and regions at possible risk are alerted by means of **Cyclone watch bulletins** and **Cyclone Warning Bulletins.**

Issuance of such or similar bulletins, as distinct from Bad Weather Warnings, should serve to activate responses at different levels in the nation down to that of the community.

The media (news papers, radio, and television) should collaborate closely with the Meteorological Department or Ministry of Information to provide and disseminate actual information of relevance to the actual situation.

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Mitigating measures to reduce the adverse effects on the environment of the impact of cyclones and storm surges include actions to ensure that natural barriers are provided and remain intact. These will include planting of trees, such as mangroves, and taking steps for the protection and preservation of coral reefs and sand bars.

Particular care should be taken to minimise the exploitation of these natural features for construction materials during the repair and rebuilding period following a storm. Preservation of such natural features also help to maintain the attractiveness of a region for tourism as well as helping to protect coastal roads and railways.

Regional co-operation between South Asian countries as regards environmental effects of cyclones and storm surges could take many forms.

One important aspect is improvement in early warning activities. This function is greatly assisted today by information obtained from orbiting satellites but much still remains to be developed as regards diffusing this information at community level.

Systems need also to be improved for transmitting this information to boats at sea.

Detailed surveys should be performed by littoral states of the shoreline and under water seaslope. This data would be invaluable for helping in the identification for vulnerable areas, as well.

Another invaluable aspect is detailed land use planning and its implementation for cyclone-prone areas.

This should include all r elevant aspects such as retention of marshes to act as "sinks" for flood waters, location of hotels and other vulnerable buildings behind belts of trees and other natural barriers etc. Hazardous industries should, as far as practicable, be located outside "cyclone-prone" areas.

The countries of the region should co-ordinate programs to identify alternatives to the use of sand and coral for providing materials for construction purposes. Information on these questions should be circulated among member states and tested to ascertain its usefulness under the conditions obtaining in each state.

The member state should co-operate in programs of research on the development and early detection of cyclones. It has been noted already that the development of a cyclone depends on many factors and in fact, cyclones are relatively rare considering the fact that conditions such as sufficiently warm sea surface temperatures are fairly frequently available.

It is possible that more research on cyclones will help reveal some hitherto unappreciated condition which can be deliberately disturbed in the case of necessity in order to impede the further development of the storm.

tion should be directed to developing a beneficial use of the energy source, which may prove inexpensive, renewable and free of chemical pollution.

Developing a novel technology for tapping solar energy based on the phenomena on which cyclones develop may well take even fifty years of unremitting effort but would be of utmost benefit to the region when perfected.

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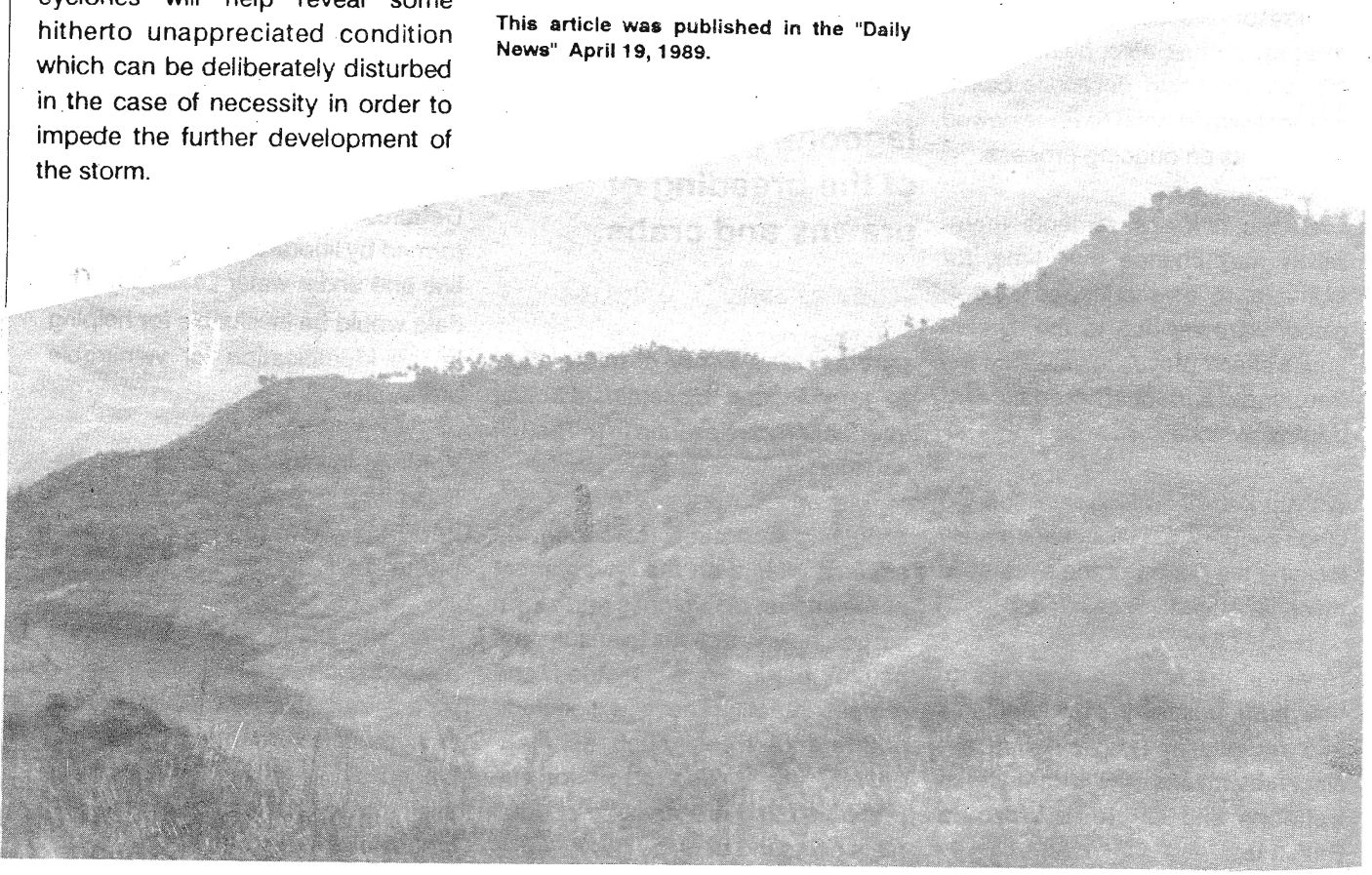

Finally, a more distant goal towards which the combined research skills of member states could be directed is to develop a means of harnessing or "tapping" the tremendous energy found within a cyclone to serve man. In view of our fortunate position in a region where cyclones form, atten-