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Environmental impacts of earthquake hazards: Indian scenario

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ABSTRACT

An overview of environmental consequences resulting due to earthquake phenomena in various parts of India, is presented. The prominent characteristics of major earthquake operations as well as the damages caused to environmental regime and human population are enumerated. The problems of earthquake prediction and control are also discussed.

Prediction of hazardous earthquake activity can be made on the different criteria such as: seismicity pattern preceding large earthquake, recurrence intervals of earthquake events, dilatancy phenomena of high strain zone, changes in groundwater levels and composition and anomalous animal behaviour. However, precise technique for short term prediction is still to be evolved.

Earthquake disasters can be reduced to some extent by adopting adequate remedial measures before, during and after the activity. It is opined that the environmental awareness should be exercised to educate people regarding the defensive operations to protect themselves from adverse effects of earthquakes. The appropriate steps such as schemes of landuse planning, regulation of structural design, and provisions of earthquake insurance programmes may be considered for implementation on priority.

INTRODUCTION

The main aim of the present paper is to visualise the environmental profile of earthquake hazards with particular reference to Indian region. An attempt has been made to analyse the available informations in respect of various major catastrophic earthquakes that have occurred in different parts of Indian subcontinent. The current problems of precise prediction and appropriate mitigation of earthquake events have been discussed. The suitable steps for timely accurate prediction and guidelines to cope with the hazardous aspects of earthquakes to environmental settings are suggested.

EARTHQUAKE OCCURRENCES IN INDIA

In the Indian subcontinent, earthquake events of varied degree occur in the Himalayan Indo-Burman ranges in the north, south-central part of Pennisular India and the Koyna-Broach-Kutch belt in western India (Valdiya, 1987).

It has been observed that the great earthquakes occur mostly at plate boundaries whereas the major and moderate earthquakes may occur also in the interior of Indian plate (Gaur, 1993). The earthquakes of intermediate depth (180 to 300 km) have been recorded from Burma and Hindukush regions (Rastogi, 1981).

The earthquakes of high magnitudes have been observed in the outer belt of the Himalaya. More than twelve earthquakes equal to or extending magnitude 7.5 have been recorded in the Himalayan region during the last 100 years (Gupta, 1993). The seismic activity in Peninsular India is mainly confined to NNW-SSE and NE-SW trending faults and fractures (Valdiya, 1987). The major damaging earthquakes, which occurred in India and adjoining regions are listed in Table 1.

Table 1 : Significant Features of Important Major Damaging Earthquakes occurred in Indian subcontinent (Data are based on available informations).

Date of occurrence	Location	Epicentre Lat.N.	Epicentre Long.E	Focal Depth(Km)	Magnitude (M)	Intensity (MM)	Environmental Impacts No. of deaths caused / Damages of structures
11-10-1737	Calcutta, W. Bengal	22.60	88.40	—	—	VIII-IX	3,00,000 people died.
17-06-1803	Kachuhh (Kutch)Gujrat	—	—	—	8.0	IX-X	1,500 people died.
06-06-1828	Srinagar, Kashmir	35.00	77.00	—	6.0	X	>1,000 people died.
12-06-1897	Shillong, Meghalaya	25.90	91.80	18.25	8.7	XII	1,600 people died. Thousands injured. Severe damage over 414,000Km², Shilling town completely ruined. Landslides occurred, alluvial tracks fissured and riddled with vents.
.04-04-1905	Kangra,Himachal Pradesh	33.00	76.15	44-100	8.6	IX	20,000 people died. Townships and villages in the meizoseismal zone were ruined. Wide spread landslids occurred. Dehradun area raised by 13.4cm.
08-07-1918	Srimangal (Bangladesh)	24.50	91.00	21-25	7.6	X	Very few people died. Severe damage of property near Srimangal. Poorly constructed houses were collapsed.
02-07-1930	Dhubri, Assam	25.80	90.20	25-32	7.1	IX	Very few casualities. Some damages occurred at Dhubri & Garo Hills. Poorly constructed houses were collapsed.
15-01-1934	North Bihar-Nepal	26.50	86.50	39-79	8.4	>VIII	11,000 people died. Severe damages took place over 93,240 Km².Monghyr & Bhatgaon ruined.Landslides occurred near Kathmandu, Udaipur, Garji & Eastern Nepal
30-05-1935	Quetta (Pakistan)	29.50	66.70	—	7.6	X	30,000 people died.
29-07-1947	North East Assam	28.50	94.00	—	7.9	—	> 1,500 people died.
15-08-1950	Assam-Eastern Arunachal (Rima)	28.50	96.50	28-50	8.7	XII	1,530 people died (500 died due to subsequent flood). Several damages recorded over 194,250 Km². Widespread collapse of buildings were observed in Upper Assam. About 40-50 of wildlife perished in hilly tract. The property loss was about Rs.61,00,000. Arte sian wells and tube wells were chocked.
10-12-1967	Koyna, Maharashtra	—	—	11-14	6.4	VIII	>2,000 people died. Township was damaged. Temporary constructions in Koynanagar area were collapsed.
19-01-1975	Kinnaur, Himachal Pradesh	32.45	78.43	18-22	6.8	IX	60 people died & 40 injured. About 2000 houses were collapsed.
14-06-1976	Dharamsala, Himachal Pradesh	32.17	76.33	—	5.0	—	Old buildings in Dharamsala and Macleodganj were partlydamaged.
29-07-1980	Dharchula Bajang (Indo-Nepal Border)	29.56	87.07	—	6.1	—	Most buildings in villages Kalka and Gothi were fully damaged.
08-08-1980	Jammu-Kathua	32.89	75.56	—	5.5	—	15 people died. 2887 houses partially and 1312 buildings were fully damaged.
26-04-1986	Dharamsala, Himachal Pradesh	32.10	76.30	—	5.7	—	3 people died.16500 houses developed minor cracks. 137 buildings were fully damaged.
21-08-1988	Bihar-Nepal Border	26.75	86.61	57	6.5	VIII	>1000 people died (Nepal - 700, Bihar -> 300). About 50,000 houses were affected (several thousands collapsed).
20-10-1991	Uttarkashi, Uttar Pradesh	30.75	78.86	12	6.1	VIII	2,000 people died (1000 injured). 20,184 houses were totally damaged and 74, 714 houses were partially destroyed. The well engineered and constructed houses even in meizoseismal area withstood this terrible shock.
30-09-1993	Latur (Killari) Maharashtra	18.02	76.32	5-15	6.5	—	10,000 people died. >14000 people injured. Widespread collapse of adobe type and random rubble masonry construction in the epicentral tract. More than 35,000 houses had suffered various degrees of damage.
22-05-1997	Jabalpur, Madhya Pradesh	23.10	80.10	—	6.0	VIII	48 people died. (1000 people injured).More than 50,000 houses were damaged. About 7000 houses were completely destroyed.

ENVIRONMENTAL IMPACTS OF EARTHQUAKES

The earthquake activity is one of the most catastrophic and dangerous event of the nature. It causes a severe problem particularly when people reside close to a earthquake prone location. It has been observed that out of one million earthquakes occurring every year, only two earthquakes on the average, have high magnitude of more than 7.75 to cause catastrophic damage (Keller, 1976). It has been estimated that the earthquakes have caused deaths of more than 100 million people throughout the world and the twentieth century annual toll is about 15,000 (Coates, 1981).

The environmental damages caused by various major earthquakes occurred in Indian and adjoining region have been enumerated in Table 1. It has been observed that areas of high population density are more vulnerable to earthquake disasters.

PREDICTION OF EARTHQUAKE

The survey of records reveals that the reliable scientific research on earthquake prediction has been first carried out in the United States of America, Japan and China and is now being followed in other countries. The comprehensive account of research work on earthquake forecasting is available in review/research publications by Rikitake (1976, 1981, and 1982), Simpson and Richards (1981), Asada (1982,1986), Shah(1984), Gupta (1992), Guha (1994) and others.

The earthquake prediction process involves the specification or forecast of time interval, place (geographical area) and magnitude of future earthquake. The information on seismicity gaps and recurrence rates in a particular region has been used for predictions of earthquakes. The identification of possible area of earthquake occurrence requires the search of precursor events that occur before major earthquakes (Kisslinger, 1975).

The earthquake prediction studies are based on the models of earthquake generation processes. The physical models such as (1) Dilatancy Diffusion Model of Scholz et al. (1973) and (2) Dilatancy Instability Model of Mjachkin et al. (1972, 1975) have been used to visualise the premonitoring phenomena expected to occur before future earthquake.

The effective earthquake precursors are: land deformation, tilt and strain, foreshocks, anomalous seismicity, b-value source mechanism and velocity ratio Vp/Vs, seismic velocity, geomagnetism, resistivity, radon anomaly, groundwater level, off flow, abnormal animal behaviour and unusual colour of sky (Guha, 1994).

The geological and seismological data have been used for predicting the magnitude and intensity of damaging future earthquakes. The most reliable basis for earthquake forecasting is the analysis of microseismicity patterns preceding major earthquake events (Valdiya, 1987). According to Jones and Molnar (1976) the possiblity of macro earthquake occurrence can be predicted on the basis of foreshocks that occur days or hours before the main activity. For example, the prediction of Haicheng earthquake (M 7.3) of 4 February, 1975 in China was made on the basis of records of foreshocks. This major earthquake destroyed 90% of the structures but human lives have been saved by issuing warnings on 3rd February 1975. However, Chinese seismologists could not predict the Tangshan earthquake (M 7.8) of 28 July, 1976, because it was not preceded by foreshocks. The earthquake resulted in death toll of 2,40,000 people (Valdiya, 1987).

It has been observed that all great earthquakes of $M \geq 8$ were preceded by seismically quiescent period - 19 years in the case of Kangra event and 28 years in 1897 Meghalaya earthquake (Khattri and Tyagi, 1983). The seismic zoning map of India indicate a quiescence in the Garhwal-Kumaun Sector and in the Assam Gap (Khattri and Wyss, 1978; Khattri, 1992). According to Guha and Bhattacharya (1984), the Assam Gap is expected to be "rocked by a major earthquake of M~8.25 towards the end of this century".

Based on the evidence of changes in velocity ratio of P and S waves, Aggarwal et al. (1973) made a successful forecast of M 2.5 earthquake on 1 August 1973, which occurred after two days on 3rd August 1973 in the Appalachian region (U.S.A).

The monitoring of electrical resistivity and abrupt change in radon gas concentration provide precursor indication of earthquake event. The Tashkent earthquake of 1966 is an example of prediction based on radon gas. In this case, radon gas increased in deep well two times of its normal value before several years of the earthquake event and it became normal after the earthquake activity. The long term indication of large earthquake has been revealed by the uplift and subsidence of the ground.

The predictions of earthquakes have also been attempted on the basis of abnormal behaviour of animals in China, Japan, and Soviet Union. In China, Haicheng earthquake of 1975 was predicted on the evidence of abnormal behaviour of animals and also on erratic fluctuation in the water table over a large area (Deng et al., 1981). Ignatosyan, et al. (1990) documented an elaborative account of observations on abnormal behaviour of animals before Spitak earthquake of December 7, 1988.

In India, an attempt has been made in north-eastern region, to search precursors that precede major earthquakes. Gupta and Singh (1986), based on the recognition of the swarm and quiescence before the occurrence of main shock, predicted the possiblity of an earthquake in the vicinity of Indo-Burma region. The earthquake which was predicted to occur till the end of 1990 was occured on 6th August 1988. The occurrence of earthquake and forecast parameter described by Gupta (1992, 1993) are shown in Table 2.

The multidisciplinary approach has been recommended as effective means for earthquake prediction. The appropriate applications of varied types of precursors such as long term, medium term and short term have been considered as essential requirement for earthquake prediction (Guha, 1994).

REMEDIAL MEASURES FOR EARTHQUAKE MITIGATION

Several methods have been used to solve the problem of earthquake control (Coates, 1981), These methods include: (1) The deliberate initiating of small events in order to prevent the continued accumulation of stress which would ultimately cause a single major event. This can be achieved by causing rupture of rocks. (2) The dewatering by extensive pumping operations on saturated and permeable fault zones through series of drill holes in an active zone. (3) Nuclear detonations along proved hazardous faults which include creeps into fault zone. This can be done by injecting fluids through wells and holes (Valdiya, 1987). Thess three processes temporarily control or delay the earthquake occurrence (Coates, 1981; Valdiya, 1987).

The maximum number of casualities and destructions in an earthquake are resulted due to collapse of man-made structures. Hence to reduce deaths, attention should be given to design and construction of earthquake resistant houses.

It has been observed that any operation for earthquake control involves several consequences. Coates (1981) stated that 'It is possible that one particular area might be controlled in part, but stress build up might occur at an unsuspected locality where seismic activity might be enhanced. Thus prevention at one spot might cause a disaster at another. The legal ramifications of such actions are immense and the typical environmental laws of trespass and negligence would probably be applicable'.

Table 2: Predicted and actual occurrence of Indo-Burma Border Region Earthquake of August 6, 1988 (modified after Gupta, 1992, 1993).

Earthquake Parameters	Forcast of Earthquake Indo-Burma Border Region (Gupta and Singh, 1986)	Occurrence NEIS (Preliminary determination)
Epicenter	Lat.21^{0}N to 25 1/2^0 N Long.93^{0}E to 96^{0}E	25.149^o N 95.127^0 E
Magnitude	8 ± 1/2	7.3
Depth	100 ± 40 Km	90.5 Km.
Time	February 1986 to December, 1990	August 6, 1988 (00.36.26.9 GCT)

The adjustments to earthquake hazards can be made by landuse planning, insurance, evacuation, disaster preparedness and bearing the loss (Botkin and Keller, 1982). The reconstruction phase following a disaster include stages such as (1) Emergency work (2) Restoration of services and communication lines, and (3) Reconstruction.

Sharma (1988) remarked that the earthquake impacts in the economy and life line structures can be reduced by proper monitoring of active fault zone and design of buildings.

Arya (1990) studied a damage scenario of great Kangra earthquake of 1905 which caused 20,000 human lives and widespread damages. According to him, if this earthquake was to repeat today, the range of human lives lost will be between 88,000 and 3,44,000 depending upon the time of day and season when it occurs. He pointed out that 'the real approach to earthquake disaster reduction lies in preventive actions before the future event. Knowledge has sufficiently advanced to permit not-to-expensive earthquake resistant constructions'. He further remarked that "Earthquake disaster reduction is a distinct possiblity by careful preventivę engineering measures which require only minor extra expenditure to what is required for normal construction".

Khattri (1992) suggested the need of coordinated programme to refine seismic hazard maps, Gupta et al. (1993) emphasised the necessity of updating of seismic zoning of the country. Nandy (1995) proposed ten suitable parameters for consideration in the seismic hazard assessment programme.

An important role can be played by geologists in earthquake mitigation programmes by providing pertinent data, maps and reports of earthquake hazardous area to planners and policy making groups. The need of formulation of a national agency namely, "Natural Hazard Management Commission for Planning Disaster Preparedness" has been suggested by Valdiya (1987, 1993). Gaur (1993) opined that "We must therefore learn to live with earthquakes on the terra infirma by intelligent design of human dwellings and engineering works, for which systematically applied and rigorously implemented modern scientific approaches offer considerable promise".

The most effective measures to protect people and property are education and legislation (Coates, 1981). The popularisation of the education on defence against earthquakes and mitigation of damage to all people even in the areas considered safe from the earthquake has been stressed by Deshpande (1994). Several agencies such as the Federal Emergency Management Agency (FEMA), National Science Teachers Association (NSTA), U.S. Geological Survey (USGS), and Non Governmental Organisations/Individuals namely, `Mesdeos' are engaged in educating the people by providing illustrative literature to adopt defence measures against earthquakes.

The predictions of possible earthquake hazards and proposals of appropriate measures of mitigation provide scope of more work to be carried out (Gupta, 1992). The earthquake hazard mitigation through both earthquake prediction and control is still in developmental stage. Guha (1994) remarked that "we can hope for significant earthquake hazard mitigation in furture and perhaps to control one of the natural disasters of today".

CONCLUSIONS

The phenomenon of earthquakes can not be stopped from occurrence, however, some preventive measures can reduce the severity of damages to human lives and property by making timely prediction of possible future earthquake. It has been observed that some of the earthquakes have been predicted and timely implemented steps have minimized the adverse impacts. The prediction process is based on the identification of precursors that precede before an earthquake event. The precise technique for short term earthquake predicition is yet to be developed by seismologists.

It can be mentioned herein that the earthquake hazard mitigation through accurate prediction and control is still a challange to scientists and it may be possible in future by innovation of advanced technology. A model for earthquake prediction and control is suggested (Fig. 1).

It is suggested that the suitable steps should be taken up well in advance to face the hazardous impacts of earthquake activity. The schemes of

Earthquake occurrence in Indian Region

- Extra-Peninsular Region.
- Indo-Gangetic Plain
- Peninsular Region

Environmental Impacts

- Loss of Human Population
- Damages to structure
- Disruption of civic facilities
- Regional subsidence or
- emergence of landmass

EARTHQUAKES

Occur in Geodynamically active Zone. Sudden shaking of earth in response to rock movement along a fault or volcanic activity'

Criteria of Forecasting

Geological and seismological data
- Seismic Gaps
- Recurrence Rates
- Abrupt changes in physical properties.
- Abnormal behaviour of animals

Problems of Prediction

- Social
- Economic
- Political

EARTHQUAKE PREDICTION

Specification of time, place and magnitude of the future earthquake

Predictions are short term, Medium term, and long term,

Advantages of Prediction

Reduction in death control

Reduction in property damage

Successful prediction of Earthquakes

U.S.A., China, Japan, USSR and India.

Methods for Contro

- Initiation of small events to prevent accumulation of stress.
- Dewatering by extensive pumping operations
- .Nuclear detonations along proved. hazardous faults

EARTHQUAKE CONTROL

Multidisciplinary Approach

Control is possible by precise prediction & appropriate mitigating measures

Suitable Measures.

- Accurate predictionof future earthquake.
- Environmental Awareness - Education to defence against earthquake
- Construction of earthquake resistant structures
- Implementation of schemes:- land use planning, structural design, and insurance.
- Large scale control can be possible by invention of advanced technology.

Earthquake Hazard Management

- Monitoring of Hazard Zoning Map
- Appraisal of risk assessment
- Restoration of services & communication lines
- Reconstruction of building structure.

Fig. 1: A model for earthquake prediction and control.

land-use planning, regulation of structural design and provisions of earthquake insurance programmes may be considered on priority basis with a view to cope with disastrous impacts of earthquake event.

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