Earthquake Early Warning System and its implementation in India

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Earthquake has been one of the major natural calamities and has taken a heavy death toll in last several centuries. Since the last two or three decades or so, a number of researchers have been trying to find whether the occurrence of any destructive earthquake could be predicted well in advance[1–3]. Till now there is only one case of successful earthquake prediction – the Haicheng (China) earthquake of magnitude 7.3, on 4 February 1975. This earthquake prediction was mostly on the basis of usual geological and geophysical parameters and also on abnormal animal behaviour. After the occurrence of any destructive earthquake, there were reports that unusual animal behaviour was observed some hours before the occurrence of the earthquake. Despite these repeated reports and observations, most researchers refuse to believe the reliability and veracity of abnormal animal behaviour. The probable reason is that the logic and science of the abnormal animal behaviour is not clearly understood. There are a few reports giving some cases of abnormal animal behaviour[4–7]. However, the Chinese could not predict the Tangshan earthquake which occurred within a year or so of the Haicheng earthquake and took a death toll of about 300,000 lives. After this, the Sichuan earthquake of magnitude around 8.0 in May 2008 could not be predicted as well. Since then, a number of scientists have been trying to find a solution to the problem of earthquake prediction. Researchers all over the world are trying to find out whether it is possible to predict earthquakes effectively on short term or very short term basis (few hours before the event)[8–10]. In Japan, Hayakawa[11] had done some pioneering work on short-term earthquake prediction using total electron content. The hind casting of Izmit earthquake (Turkey) has been discussed using GPS technique[12]. In most cases, scientists try to observe deviation of several geological, tectonic, seismological and geotectonic parametric values which is not normally observable. We are yet to meet a seismologist who can boldly say that earthquake can be predicted.

All the above parameters could be measured on a 24 × 7 time basis, independent of whether an earthquake is due or not. The deviations in the parameter outside the regular or normal variations could be examined as precursors to a medium to major earthquake. These tests have been found quite useful and apparently successful during the post-seismic examination such as hind-casting. For the purpose of prediction, forecasting or hind-casting a number of geological, geophysical and tectonic parameters have been used, but still no definite signal has been observed that would predict the occurrence of an earthquake. Perhaps understanding the earthquake mechanism could give some clues. As such, one is forced to infer that prediction of earthquakes is highly complex involving several parameters.

The return periods of earthquakes vary with magnitude. Small magnitude earthquakes, $M < 5.5$ or so, normally do not cause much noticeable damage. Return periods for such earthquakes vary between 5 and 10 years depending upon the seismicity of the region. Damages and destruction during moderate to large and very large magnitude earthquakes are severe and extensive. The return periods of such earthquakes are in the range 40–100 years depending upon seismicity of the region. Considering these, it would be desirable to divide the earthquake prediction into various time frames. These are normally divided into three categories: (a) long term, usually more than one year before; (b) intermediate term, usually 3–12 months before an earthquake and (c) short term, usually less than a few weeks or days. Statistical probabilistic prediction could be one such parameter where the time of occurrence of an earthquake could be in few years.

With this background, it would be appropriate to examine the Early Warning System (EWS) developed by a California researcher[8]. The name is taken from the Missile Defence System that was developed during the Cold War to protect USA against ICBM launches from the then USSR. The velocity of *S*-wave is about half the *P*-wave velocity (about 3.4 and 6 km/sec respectively). The EWS issues an earthquake warning immediately when it records the *P*-wave. As *S*-waves cause most of the damage during earthquakes, the EWS uses the difference of travel time in *P*-waves and *S*-waves to issue a warning signal of an imminent earthquake. Some seismologists are promoting the EWS solution as a 'magic wand'[8].

The first vibrations are detected when the *P*-waves arrive, compressional waves that travel with a speed 6 km/sec. When seismic sensors pick up these fast *P*-waves, seismometers linked to supercomputers at a central station can determine within seconds whether the particular seismic event is a small local tremor or a 'big one'. Automatic alerts would then be issued within seconds to give people time to react; under special conditions of magnitude 8 and 9 earthquakes warning could be up to 100–150 sec, depending on the distance from the epicentre. Japan has pioneered such systems since the 1995 Kobe earthquake, which killed more than 6000 people. The Government invested billions of yen in seismic and geodetic networks to detect quake signals. In 2004, the Japan Meteorological Agency tested a limited earthquake-warning system. It delivered its first alert in 2005, and in 2007 the system went national and public. The first true test came during the Tohoku-Oki earthquake. This helped in stopping a fast-moving train at a distance of about 250 km from the epicentre. However, the EWS in Japan could not save a single life.

It is possible that the above details and discussions about EWS may result in the impression that prediction of earthquakes is possible. However, this is not the case. The entire administration and scientific community is keen to save lives of people during any destructive earthquake. But it has to face two opposite trends in earthquake studies and disaster management. Some scientists are claiming to have reached close to the objective of earthquake prediction with possible use of EWS. On the other hand according to some disaster managers and engineers, earthquakes cannot be predicted. This is a skewed situation.

What is not clearly enunciated in the discussions surrounding the EWS since its public presentation in USA, is that the time needed to determine that a local tremor is about to develop into a major damaging earthquake will be, under optimal conditions, about 5 sec. However, if it takes a minimum of 5 sec to determine that a large earthquake is on its way, the destructive *S*-waves, propagating at speeds around 3.8 km/sec, will already have travelled at least 19 km. The value of $V_s = 3.8$ km/sec is used by India Meteorological Department (IMD) for Himalayan earthquakes. Therefore, the EWS is burdened with a dead zone, politely called the 'blind zone', about 20 km in all directions, where no warning can be issued, not even a fraction of a second.

Since 19 km happens to be the radial length of effect and the seismic waves travel in all directions, the effective area of destruction or highest isoseismal would be of about 19×2 (38 or roughly 40 km). Mathematically this indicates that the maximum area of destruction would not have any so-called warning from the EWS system. In any large magnitude earthquake, the destruction and heavy damages are confined to the highest isoseismal of about 40–70 km radius[13].

Archives of major destructive earthquakes in India indicate that when a large earthquake occurs, the chance of total destruction is highest within an area of 30–70 km of the rupturing faults depending upon the magnitude of the earthquake. Beyond 70–100 km, the effects can still be damaging but less than the total destruction. At any rate, while 5 sec may sound like a relatively long time, this is not enough for any person to run to a safe place inside the house or even run out of the house to a safer location.

The EWS could be useful in large installations, or Rapid Transit public transport systems. The Japanese bullet trains, running at speeds more than 250 km/h, can be brought to a halt within few seconds using emergency brakes. Electrical power plants, conventional or nuclear, could initiate shut-down procedures upon receiving a EWS alert, although many large plants may require a few minutes to effectively shut down. Elevators in high-rise buildings in large towns and cities could be programmed to stop at the next floor and automatically open the doors. Surgeons in operating rooms in hospitals could benefit from hearing the EWS siren even seconds before the onset of shaking to interrupt surgical procedures.

According to newspaper reports, the Indian administration is planning to install a EWS in the Himalayan region. Two such locations in the northwest in Uttarakhand and northeast Himalaya have been targeted by them. In case the EWS system is installed in Himachal Pradesh or Uttarakhand, it could give about 20–25 sec warning to large urban locations in the National Capital Region of Delhi (NCR Delhi). Similarly, EWS in the northeast region could give up to 22–35 sec warning for Guwahati, which has several tall structures. NCR Delhi may not suffer due to *S*-wave damage, but the seismic damage could be due to Rayleigh waves which could harm tall ($h > 17$ m) structures[10]. This would not help in saving people in the epicentral area. Depending upon the location of the epicentre, Guwahati could suffer from *S*-wave damage if the earthquake epicentre is within 100–150 km from the city. Also Guwahati could suffer from damages due to Rayleigh waves, if the earthquake epicentre is about 500 km or less from the city. In order to have an effective and useful seismic alert the so-called warnings from the EWS at Delhi and Guwahati would have to modify and update their computerized system. This would help in proper issue of alert signal. The Institute of Seismological Research (ISR), Gandhinagar is also installing an EWS in the Kachchh region with a view to obtain earthquake alerts in Ahmedabad[9].

In India the death toll due to large-magnitude earthquakes is very high. The primary and most significant aim of the entire Seismic Disaster Management is to save the lives of people. But looking at the EWS as life-saving device would be totally wrong. It would not help in saving any life in the epicentral area. The Disaster Management agencies in India and other seismically vulnerable countries may weigh the pros and cons of EWS before accepting the technology.

The cities and towns in the proximity of the faults, such as Shimla, Dehradun, Dibrugarh, Nainital, Itanagar and Aizwal would not get any warning regarding earthquakes. Though a EWS may be installed, it would not give even 1 sec warning if the seismic event is large. Instead, it would be more useful to concentrate on earthquake engineering measures, such as base isolation, use of neoprene-type membrane between two floors to reduce the effect of vibrations, computerized or actual test on a shake table of a model, etc. to make structures safe and earthquake-resistant.

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