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ORIGINAL RESEARCH ARTICLE

Study the bio-potential parameter for the detection of seismic and environmental changes in Indian region

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ABSTRACT

The changes the magnetic flux generated (electric, magnetic and electromagnetic waves) on the surface of earth due to sudden changes is a matter of discussion. These emissions occur along the fault line generated due to geological and tectonic processes. When sudden changes occur in the environment due to seismic and atmospheric variations, these sensing was observed by creatures and human bodies because the animals and trees adopt the abnormal signals and change the behavior. We have analyzed the changing behavior of recorded signal by live sensors (i.e., banyan tree). So we use the deep-rooted and long-aged banyan tree. The root of banyan tree (long-aged) has been working as a live sensor to record the geological and environmental changes. We record the low frequency signals propagated through solar-terrestrial environment which directly affect the root system of the banyan tree and changes that have been observed by live sensors. Then, very low frequency (VLF) signal may propagate to the earth-ionosphere waveguide. We have also analyzed the different parameters of live cells which is inbuilt in latex of the tree, so we record the dielectric parameters of green stem latex and found some parameters i.e., dielectric constant (ε) and dielectric loss (ε') of various trees to verify these natural hazards and found good correlation. Therefore, we can say by regularly monitoring the bio-potential signal and dielectric properties of banyan tree and we are able to find the precursory signature of seismic hazards and environmental changes.

Keywords: Dielectric Constant; Dielectric Loss; Earthquake; Latex; Seismo-electromagnetics

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1. Introduction

Earthquake is a very devastating phenomenon occurred in earth surface due to sudden moment of plate tectonic theory. Earthquake prediction is a new area of research at present, which serves as a promising tool in finding the natural hazard and minimizing loss of life and property. It is nevertheless not that easy to identify the seismic signals when a terrible earthquake is about to come. When rocks collided with each other, low level electromagnetic waves were generated in the vicinity of prone area. If we have access to detect such waves, it will help us to predict the precursory signature of earthquake, thus enabling us to define the time, place and magnitude of earthquake. However, scientists still have difficulty in predicting and analyzing such low level electromagnetic waves, because these abnormal signals may originate before every natural hazard, for instance, before the initiation of active volcanoes, landslides, earthquakes, hurricane, tsunami and so forth. Here, we focus on seismic electric signals or activities, which consist of series of waves originated before the commencement of earthquakes in several areas in the country. Certain green plants, such as mimosa pudica, venus flytraps and banyan trees, with deep root and long age, are very sensitive to electric signals. These trees can sensibly perceive the environmental changes which we use as the indication of seismic activity. Therefore, we require a system, and with the help of such system, we are able to define the precursory signature of any seismic activity. It has been reported in previous research that ground-based observations of ultra-low frequency signals and very low frequency signals (0.01-10 Hz) may show the precursory signature of earthquakes[1,2]. Many researchers have reported earthquake precursors from ground-based observations of ultra-low frequency (ULF) such as measured by Fraser Smith AC[1]. They reported the results of measurements of low frequency magnetic noise by two independent monitoring systems prior to the occurrence of the Ms = 7.1 Loma Prieta earthquake of 17 October 1989. Their measurements cover 25 narrow frequency bands in the more than six-decade frequency range 0.01 Hz-32 kHz, with a time resolution varying from a half hour in the ULF range (0.01-10 Hz) to one second in the extremely low frequency (ELF)/VLF range (10 Hz-32 kHz). The ULF system is located near Corralitos, around 7 km from the epicenter. The ELF/VLF system is located on the Stanford campus, about 52 km from the epicenter. However, the ULF data have some distinctive and anomalous features. First, a narrow-band signal appeared in the range (0.05-0.2) Hz around September 12 and persisted until the appearance of the second anomalous feature, which consisted of a substantial increase in the noise background starting on 5 October and covering almost the entire frequency range of the ULF system. Third, there was an anomalous dip in the noise background in the range (0.2-5) Hz, starting one day ahead of the earthquake. Finally, it is the most compelling that there was an increase to an exceptionally high level of activity in the range (0.01-0.5) Hz starting approximately three hours before the earthquake. Further, while the systems were sensitive to motion, seismic measurements indicate that there were no significant shocks preceding the quake. Thus, the various anomalous features in our data and in particular, the large-amplitude increase in activity starting three hours before the quake may have been magnetic precursors. The results of precursory signature by electromagnetic emissions were reported by Hayakawa[3]. The electromagnetic phenomena of ground-based observations abrupt low frequency signals was measured by Varotsos P and Alexopolous K[4]. These signals have also been recorded by Gokhberg MB[5] with high frequency receivers. The propagation characteristic of low frequency signals during and before the time of seismic activities were recorded by various authors[6-8]. The characteristics of ultra-low frequency signals have less contamination, low skin depth and low attenuation propagated in seismic swarm reported by Park *et al.*[9] He explained mechanism with mathematical modeling and found that the low frequency signals propagating through large distance from epicenter has been received by resistivity of signal 1000 ohm meter for surrounding rock and 10 ohm meter for a 500 meter wide by 20 km deep fault and the mechanism of ultra-low frequency signals of electromagnetic field generation based on micro fracturing mechanism, whose creation and relaxation of charges at the walls of opening cracks ion from earthquake was explained by Molchanov OA and Hayakawa M[10]. This phenomenon is also verified by Benardi A, Gufeld IL, Hayakawa M, and Kopytenko Y[11-14]. They have been investigated thoroughly by different mechanisms and recording technique, and found that the ULF range is very prominent for seismic activity research. During the last couple of years, the seismic activities have generated unoccassionally, which has brought disastrous damage to human life and property. Various theories and mechanism have been produced to record the precursory signature of seismic activity by various researchers and such theories were approved by different experiential verifications. Among them, one mechanism is adopted in this paper for precursory study of seismic activity. The mechanism of electromagnetic energy on latex involves the transport of the electrical charges by the ions present in the biomass cell wall and cellulose. Once the electromagnetic energy encountered with the latex, randomly oriented dipoles in dielectric material may align themselves in a direction opposite to applied external electric field. The molecule absorbs the energy stored as potential energy. By the mechanism of ionic conduction and dipole rotation, polar molecules vibrate and produce kinetic energy and the dielectric properties can be studied on the energy that is being reflected, transmitted through the surface and absorbed by the materials. Each type of energy is specified with its term. Dielectric constant (ε) is the ability of material to store electric energy reported by Ramasamy S and Moghtaderi B[15]. Dielectric loss (ε') is the characteristic of material to convert the electromagnetic energy into heat, which is clearly explained by Salema AA[16]. The relationship of these two values is represented by equation as follows:

$$\varepsilon^* = \varepsilon - j\varepsilon' \qquad (1)$$

Where ε^* is the complex dielectric constant, while ε and ε' are the real and imaginary part of complex dielectric constant[15]. Loss tangent is the ratio of dielectric loss to dielectric constant. Omar and his group explained the attenuation of microwave power in materials resulted in heating, which has been compiled and characterized by EFB (Empty Fruit Bunch) for pyrolysis using microwaves as an alternative heating source[17]. EFB has been taken from a local oil palm mill and was subjected to fuel, chemical and dielectric property analysis. Notably, high water content is an advantage in microwave heating and gas water is a good microwave absorber, which results in fast drying. The dielectric properties of EFB were observed to be proportional to the moisture content. However, low values of both dielectric constant and loss of dried EFBs would require the addition of microwave absorbers for pyrolysis reaction. The dipole rotation is depended on several factors such as moisture, frequency and fiber directions as discussed by Hussein I[18]. The study of dielectric properties of oil palm shell, oil palm fiber, empty fruit bunch, hardwood (Acacia mangium, Swietenia macrophylla and Maescpsis eminii) and switch grass[16-19] were reported by various authors and they have found the same type of correlation. In this paper, we will discuss the low frequency signals generated through collision of ground particles and propagated through earth medium and received by latex in the form of potential difference, which are received by (EPR-3531) Electronic Poly-recorder to determine the internal characteristics of latex i.e., the form of waves, which will give the amplitude and intensity of the signal. We also calculated dielectric properties like dielectric constant, dielectric loss of the latex, which verify and show a very good correlation with seismic activities.

2. Experimental set-up and ionospheric data

We have installed the three-channel Electronic Poly-recorder (EPR-3531) for receiving the bio-potential signals in the form of waveform. The system has been installed in rural area nearby active fault region (Mathura-Faridabad ridge) which is far away from artificial and manmade noise and characteristics of latex have been identified by LCR Hi-Tester Meter to analyze the dielectric properties like dielectric constant (ε), dielectric loss (ε') of latex material from deep-rooted trees (i.e., banyan trees of different ages) and simultaneous observation is taken by Terrestrial Antenna installed on a college building of three stories near to recording station of bio-potential signals. We have examined the real time data with different data of ionosphere, i.e., magnetic storm data and earthquake data, and found correlation between seismic and atmospheric activity simultaneously and we will discuss it later in our result section.

Electronic Poly-recorder (EPR-3531) Hi-Tester Meter (3235-50)

Figure 1. The Electronic Poly-recorder to measure the bio-potential and LCR Hi-Tester Meter for measuring the dielectric properties**.**

In order to measure the level of the signal strength at bio-potential antenna, we have taken the observations of the natural D.C. potential with respect to banyan tree using a digital multimeter model NO. MAS830L from 1 May, 2017 to 30 July, 2017. We found that the bio-potential increased from 10 to 50 mV from 1 May, 2017 to 30 July, 2017 on the occasion of seismic events before and after the occurrence of earthquake. The root of tree works as an antenna system to record the amplitude variation of signal generated in mV. It means that when the signal strength was larger than 200 μV/m at the antenna, the amplitude was enhanced as compared to the regular signal. We recorded the enhanced signal (around 30-45 mV) during the Rohtak earthquake. The signal at the antenna was assumed to propagate through the earth-ionosphere waveguide from the epicentral region of three earthquakes during which there was not much attenuation. These signals were observed in the form of signal bursts of varying amplitude in months which have been mentioned earlier in the paper, as observed at Farah, Mathura region, and were correlated with seismic activity data. The observations were taken in rural area and the bio-potential antenna was made by inserting silver electrodes in a banyan tree of some 100 years old. It has been found that during the days of seismic activity, the bio-potential data is dominated by the emission from a seismic source, while during non-seismic days, the data has been observed in normal potential, which is around 5-10 mV. Now we made the calculation of attenuation suffered by seismo-electromagnetic signals at a frequency of 3 KHz for a model of the earth's crust, in which the signal propagated from the source region in the middle layer to the top layer of the earth's crust, through the upper layer during the precursory surface of any seismic activity. We have analyzed the data of bio-potential, terrestrial and magnetic storm from 1 May, 2017 to 30 July, 2017 and done the statistical analysis of data and then found that the seismic activity will help us in predicting the natural hazards. In this analysis, the bio-potential signals was enhanced due to occurring of seismic activity but not more enhanced in terrestrial antenna recording signals during the precursory time. We have taken the data of earthquake from Indian Meteorological Department website to choose the data of local and regional earthquake nearby around 1000 km with low depth and high magnitude. The signal is received both by bio-potential and terrestrial antenna, and the enhancement of amplitude in terrestrial antenna is received at the same time as that of bio-potential. The more enhanced terrestrial signals is eliminated by low pass filter with MATLab software.

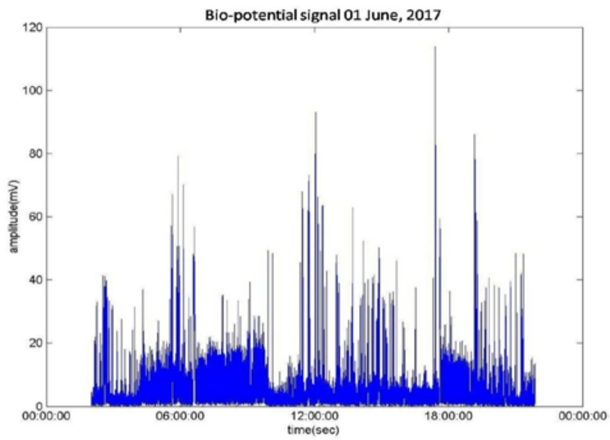

Figure 2. The signal bursts of varying amplitudes recorded by bio-potential antenna recorded at Mathura**.**

3. Results and discussion

When any seismic activity occurred under the ground, the emission has been responded with abrupt changes in amplitude, polarization ratio, statistical analysis at the time of event, before and after the occurrence of seismic activity and verified the atmospheric signals which is only recorded in terrestrial antenna instead of ground-based sensors. Now for more authentication, we have started the bio-potential study by electronic poly recorder and the internal characteristic has been analyzed by LCR Hi-Tester Meter, which have provided real mechanism of generation of seismic activity to be discussed later. We have analyzed the data of bio-potential by deep-rooted banyan tree and found that the abnormal amplitude signal was enhanced during and before the seismic activity, which was greater than the mean value. The amplitude variations of the transient change of potential difference (bio-potential) are shown by solid lines (blue color) in **Figure 2** and comparison with seismic activity data was discussed in **Figure 8**, which verified that the signal has been generated under the ground and give the explanation of atmospheric signals and bio-potential respectively. In **Figure 3**, we see the signal bursts of varying amplitudes recorded at monitoring station by terrestrial antenna. We have plotted the amplitude (mV) on Y-axis and real time recorded on X-axis for 24 hours on 1 June, 2017. The area shown by blue color lines are the signal and spikes are the noises. Terrestrial antenna measures the coupling of atmosphere-lithosphere-ionosphere. It is clear that the signal bursts recorded by terrestrial antenna was not the original frequency because it is a mixture of different attenuations by various sources like aeroplane noises, some building noises, reflection of bird and manmade disturbances. So we can say that the signal received by the terrestrial antenna was not desirable signal for authentication of a seismic activity in sub-continent region. Signals received by terrestrial antenna are the source for indication of environmental variation and seismic hazards.

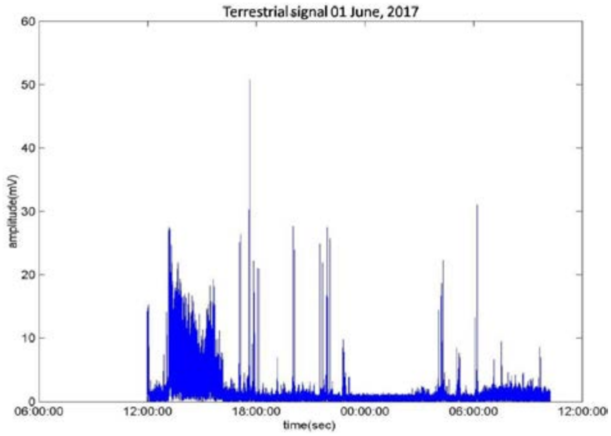

Figure 3. The signal bursts of varying amplitudes recorded by terrestrial antenna recorded at Mathura**.**

The amplitude variations of the transient change of potential difference between the two electrodes were obtained by inserting the electrodes in the tree (bio-potential) with time as shown in **Figure 2**. The signal enhancements have two possibilities. One is that the amplitudes were enhanced due to some changes in the atmosphere (i.e., seasonal variation and disturbed magnetic storm data) and the second possibility is that the amplitudes were enhanced due to the changes in potential difference between the two electrodes generated prior or during and after the earthquakes. The reason of the amplitude enhancements (bio-potential) is due to the movement of tectonic plates which create the pressure (in the form of energy) due to friction (i.e., dipping process of two plates with subduction zone and micro fracturing process). So, when any seismic activity occurred within 1000 Km region at a shallow depth, the pressure has been produced and released in the form of energy; When the energy has been come out near the root of old-aged tree, the potential has been changed abruptly. This phenomenon is responsible for the enhancement of amplitude of bio-potential data. **Figure 2** represents the signal received by Electronic Poly-recorder (EPR-3531). The signal received was further analyzed by MATLAB Software which can authentify the signal received by terrestrial antenna at the same date and time. The signal with less destruction, less noise and without attenuation of obstructs can easily be received by inserting electrodes in deep-rooted banyan tree, denoting that the concentration of xylem and phloem was received in the graphical form with the help of EPR-3531. The signal received by terrestrial antenna and bio-potential antenna are verified by the study of dielectric properties of banyan tree (100 yrs), Banyan tree (50 yrs) and akkaua tree (10 yrs) respectively. We have also analyzed dielectric properties of latex of different trees to verify the terrestrial and bio-potential signal received. It is proved that when two types of latex is available from two types of trees, it is certain that one is lower-edge and shallow in depth while the other is old-aged and deep-rooted. As we all know, when the age of the tree succeeds, the latex of the tree becomes more concentrated in comparison to lower-aged tree. The similar type of analysis has been recorded on human blood by Gaur MS[20]. When electromagnetic wave energy is just near the circular radius of tree, the root absorbs electromagnetic energy, which directly affects the latex. And the loss has been increased due to increase of frequency, whose mechanism is similar to human nature of all circumstances with pressure of different ages. We have also analyzed the dielectric properties of green stem latex and found some parameters like dielectric constant (ε) and dielectric loss (ε') of various trees and found very good correlation with online seismic activities, which may be a precursory signature of hazards. As we can see in **Figure 4**, the dielectric constant (ε) of banyan tree (100 yrs.), banyan tree (50 yrs) and akkaua tree (10 yrs) is decreasing with the increase in frequency (Hz). When frequency increased from 1 to 10^5 Hz, dielectric constant was decreased. The result depicted that electric field of Hi-Tester Meter affected the interaction of latex and electromagnetic waves. When the frequency increased, a continuous varying electric field was created. This varying electric field created polarization in Latex. Dipole moment in latex gradually decreased as frequency increased. So, dipole had shorter time to realign itself according to the oscillating electric field[2,21]. Conductive effect of electromagnetic wave heating also diminished quickly in high frequency[5]. Hence, dielectric constant which indicated the ability of material to store electric energy decreased.

Dielectric loss (ε') is the ability of material to convert the electromagnetic energy into heat. Dielectric losses of all the trees used in study were increasing when the frequency increased from 103 to 105 Hz. Beyond 104 Hz, the dielectric loss was slightly increased with the increasing of frequency. This dielectric loss trend was observed due to different electrical conductivity of long-aged banyan tree (100 yrs), banyan tree (50 yrs) and akkaua tree(10yrs) at varying frequency as reported in an earlier study of Salema *et al*.[16] When the seismic activity occurs, the dielectric loss increases because the electromagnetic waves diminish the latex of tree as reached in contact with deep-rooted trees like banyan tree. **Figure 4** deals with the study of dielectric properties of different tree roots. For more authentications of results received by both antennas, we have started the dielectric study of latex obtained from various trees like banyan tree (100 yrs), banyan tree (50 yrs) and akkaua tree (10 yrs). We have seen that dielectric constant of 100 yrs banyan tree is stronger in comparison to trees of other ages. Banyan tree is deep-rooted and the roots are reached to the faults created by movement of tectonic plates, which is the basic cause of disaster. Hence, we can say that if we regularly monitor the dielectric properties of banyan tree, we are in a position to make the statement regarding natural disaster.

We know that these variations in latex in the form of potential difference have the similar type of activity as in human's blood[20]. **Figure 5** reveals the study of dielectric loss measured by Hi-Tester Meter. We have analyzed the comparative study of dielectric loss at various frequencies. Dielectric loss of banyan tree (100 yrs) is less in comparison to other trees at same frequency under study. Dielectric properties of the latex of the banyan tree (100 yrs), banyan tree (50 yrs) and akkaua tree (10yrs) show a resemblance with the seismic activity and if we monitor the dielectric properties at regular intervals of time, they may help in giving the precursory signature of seismic hazards. Further, more studies and real time data have been required to provide better explanation for the prediction of earthquake.

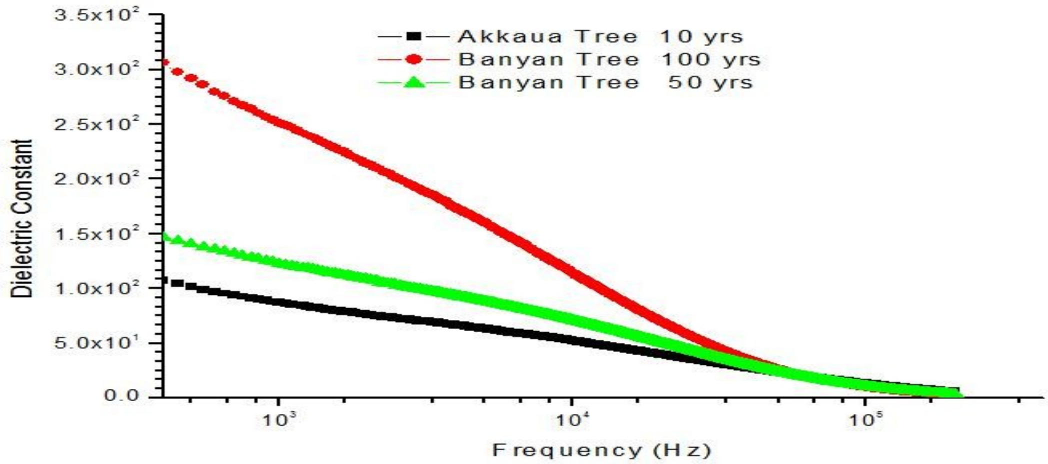

Figure 4. Dielectric constant of latex of banyan tree (100 yrs), banyan tree (50 yrs) and akkaua tree (10 yrs).

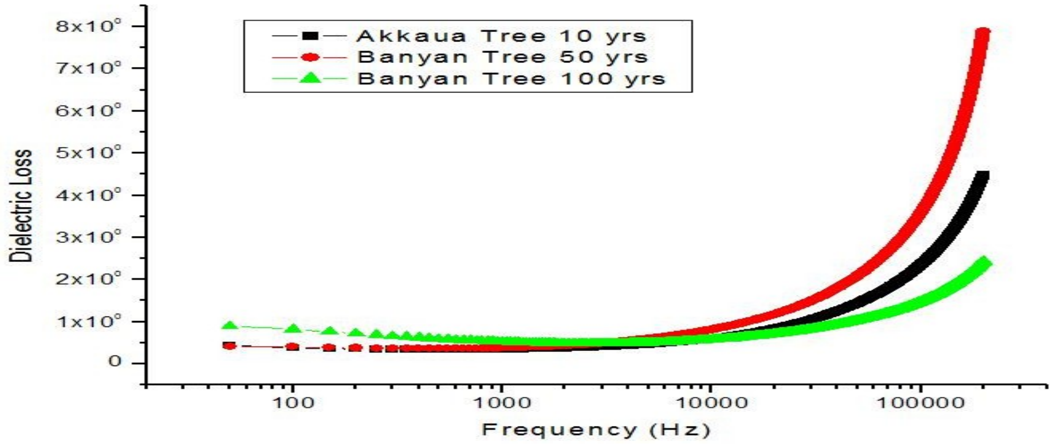

Figure 5. Dielectric loss of latex of banyan tree (100 yrs), banyan tree (50 yrs) and akkaua tree (10 yrs).

In **Figure 6**, the map shows the position of Delhi-Himalayan belt and the fault region on main boundary fault. This actual fault line created around 1880 under an impact of a big earthquake. These signals were observed in the form of signal burst of varying amplitude in recent time, whose date have been mentioned earlier in this paper, as observed at Farah, Mathura region and were correlated with seismic activity data discussed earlier case by case. The observations were taken in rural area and the bio-potential antenna was made by inserting silver electrodes in a banyan tree, around 100 yrs old. Under the guidelines of model calculation of Arora BR and Singh BP[22], we have considered two flat values of conductivities, 10^{-2} S/m for the upper layer and 10^{-4} S/m for the middle layer and calculated attenuation of magnitudes for all emissions between ultra-low frequency signals and very low frequency signals. We have taken the conductivity model of upper layer conductivity range from Tsarev VA and Sasaki V[23]. They suggested that the range of the upper layer is 10^{-2} – 10^{-1} S/M with the lower basement conductivity around 10^{-2} S/M. They also suggested that the attenuation for ELF (extremely low frequency) range of signals is between 3 Hz and 30 kHz, but it increases steeply from ultra-low frequency to high frequency signals. The model of electromagnetic signal propagation through seismic faults activity, as a waveguide, is similar to earth-ionosphere waveguide. Since there exist a long distance fault known as MBF (main boundary fault) at the northern base of the Himalayan belt, extending between north west and north east India and the seismic activity occurred in nearby 500 km radius range. It is found that active fault of Mathura-

Faridabad total region is considered as MBF, so we have recorded the signal in very precise time.

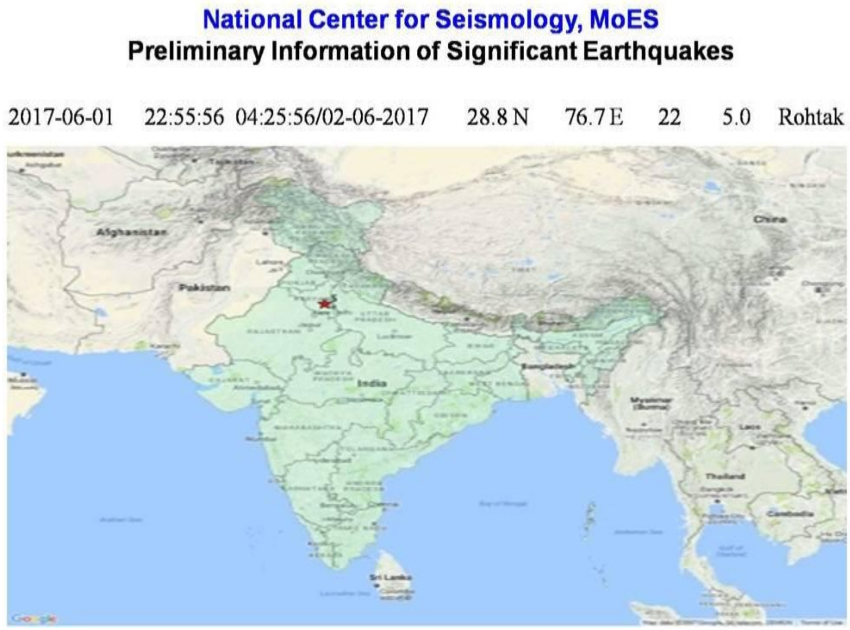

Figure 6. The position of Delhi-Himalayan belt and the fault region on main boundary fault.

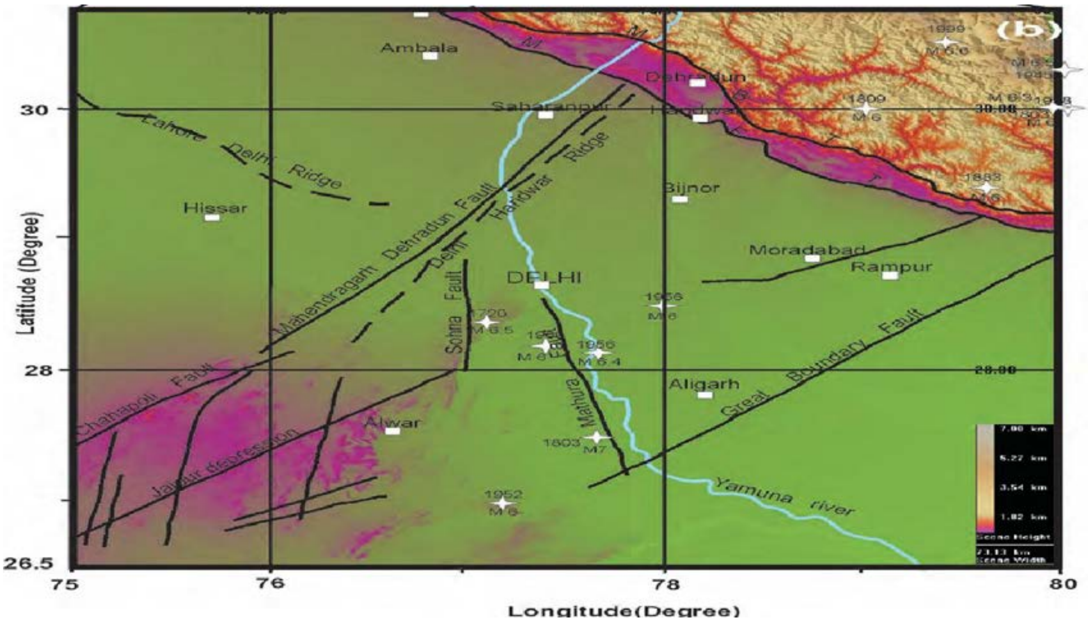

Figure 7. The earthquake of magnitude 5 richter scale taken from IMD, Delhi.

The information of earthquake we have taken from Indian Meteorological Department website shows that the seismic activity occurred on 1 June, 2017 at Longitude 76.7° E and Latitude 28.8° N. The map of seismic activity in Indian region is presented in **Figure 7**, showing the earthquakes with preferred latitudes and longitudes and the location of receiving station marked by an asterisk and earthquakes marked by star is also displayed in this map. The low frequency signal penetrated the earth surface and propagated the ionosphere was received by terrestrial antenna. So, many earthquakkes occurred at several regions in the above mentioned time period, but we have chosen the strong magnitude earthquake with reference of receiving enhanced signal and the signal is verified by various analysis, which gave clear indication of precursory signature of seismic activity.

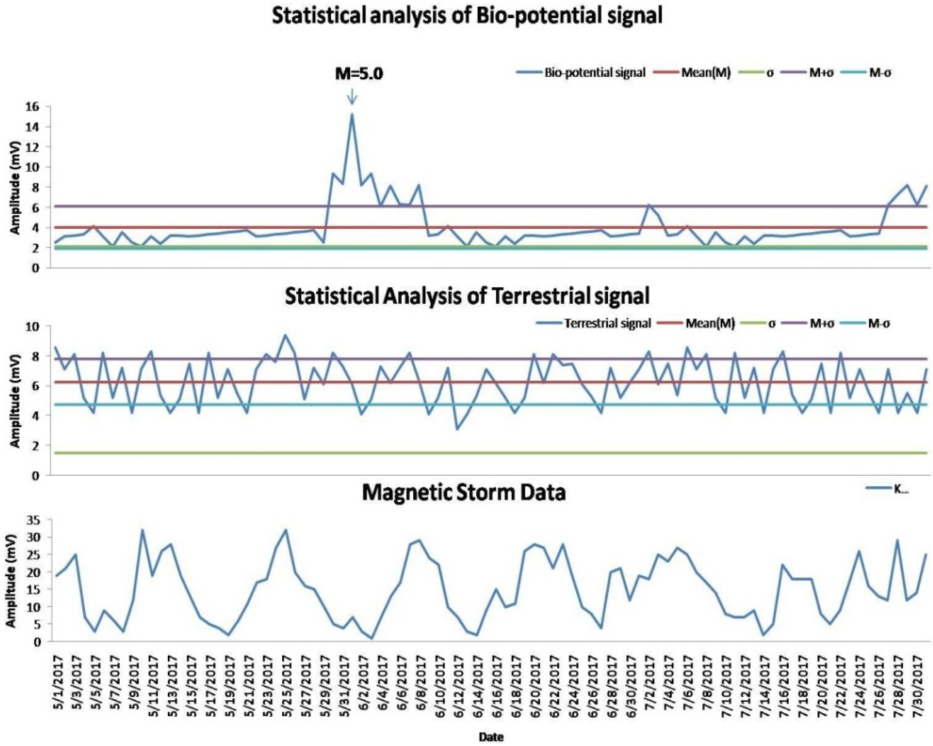

Figure 8. The statistical analysis of bio-potential signal, terrestrial signal and magnetic storm data**.**

4. Statistical analysis of data

In **Figure 8**, we applied statistical analysis to verify the data recorded by bio-potential sensor. We found that, there are the large enhancements in amplitudes from regular amplitude fluctuations, so we plotted graph on the same scale to view the changes in all the data observed at the same period from positive to negative fluctuations. The amplitude variations of the transient change of potential difference (bio-potential) are shown by solid lines (blue color) in the upper panel. Here, the amplitudes are passed within standard deviations during the whole period of analysis, and we found a day (1 June 2017 and 28 July 2017) when the amplitude was abnormally enhanced to search the possibilities of amplitude enhancement by rigorous analysis for this data. And the two possibilities related to amplitude enhanced signals have been found. One is that the amplitudes were enhanced due to some changes in the atmosphere. (i.e., seasonal variation and disturbed magnetic storm data) which is plotted in the bottom panel and the second possibility is that the amplitudes are enhanced due to the changes in potential difference between the two electrodes generated prior or during and after the earthquakes. The reason of the amplitude enhancements (bio-potential) is due to moment of tectonic plates which create the pressure (in the form of energy) like friction (i.e., micro fracturing process). So, when any seismic activity occurred within 1000 km region at a shallow depth, the pressure has been produced and released in the form of energy; When the energy has come and filled in previous fault line which are active, the electromagentic signals are moved in this fault and received out near the deep rooted old-age tree, which is worked as a live sensor. The precursory electromagnetic emissions have been generated before any seismic activity due to the inner particle of the earth (i.e., sand, which is associated with various element such as Na, K, S, Au, Ag, Fe, etc.) collided with each other by fracturing process, tectonic plate movement and electronic kinetic effect. And then the energy accumulated in the form of emissions and propagated in near active fault channel, so the bio-potential is enhanced due to very complex region and other enhancement recorded on 28 July, 2017. Due to the enhancement of magnetic storm data generated from sun penetrating the ground surface of the earth, it is necessary to distinguish the enhanced bio-potential signal between earthquake and magnetic storm.

5. Conclusions

We have analyzed the data of bio-potential, terrestrial and magnetic storm from 1 May, 2017 to 30 July, 2017 and found that the study on seismic activity will also help us in predicting other natural hazards after a series of statistical analysis. In this study, we compared the dielectric properties of 100 yrs banyan tree, 50 yrs banyan tree and 10 yrs akkaua tree and found that dielectric constant of 100 yrs banyan tree is stronger in comparison to 50 yrs banyan tree and 10 yrs akkaua tree. We also compared dielectric loss of 100 yrs banyan tree, 50 yrs banyan tree and 10 yrs akkaua tree and found that dielectric loss of 100 yrs banyan tree is less in comparison to 50 yrs banyan tree and 10 yrs akkaua tree. It means the 100 yrs banyan tree has more strength to sense the electromagnetic waves originated during and before any seismic hazards. This natural disturbance causes the increase of relaxation process and produces the change in bio-potential from time to time in order to develop a clear understanding of this process. We have conducted the experiment to measure relaxation process by means of dielectric properties. Consequently, we can say dielectric properties are also helpful in verifying the precursory signature of seismic activity. We conclude that when the higher magnitude signal or high energy signal reach in contact with latex of banyan tree roots, it absorbed the energy while the latex is shrinking during the time, which is a precursory signature of seismic hazards. We identified the different parameters correlated with the mechanism of dielectric properties of materials i.e., similar to human blood[20]. We recorded the signal in terrestrial antenna and electronic poly recorder to study the dielectric properties of banyan tree, which is verified by statistical analysis, and we found that there are very good correlation between them. It means we are in a position to say that we are able to predict the precursory signature of any seismic hazard occurred in nearby fault region save the life of the people and provide disaster forecast for the future.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgements

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