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Biosensor and its Applications

Awadhesh Kumar Singh[1]* and Narendra Singh[2]

[1]*Maharaja Agrasen Institute of Technology, Rohini, Delhi, India*
[2]*Gaya College, Magadh University, Gaya, India*

Abstract

It is well known that animals/birds respond to earthquake much before its occurrence, especially dogs, rats and crows. They keep themselves safe by sensing it, well in advance. Responsible biomolecules present in their body for this sensing system can be used as an earthquake sensor. When pharmacology of dogs, rats and crows are further studied, it is found that their blood pressure/pulse-rate is also in the same range, or even higher as in a human body suffering from high blood pressure, i.e. around 150-180 diastolic pressure. Pulse rate of crow=380 beats/min, rats=420 beats/min and dogs=120 beats/min (normal human body=75 beats/min). Human body is also very sensitive to feeble vibration, when suffering from hypertension/high blood pressure, resulting in higher pulse rate. It means that biomolecules active during high blood pressure are responsible in sensing the feeble vibrations in the human body. Sensing behavior of that biomolecules can be exploited to sense the earthquake. In human body, crows and dogs/rats, it is Norepinephrine (NE). So, behavior of NE or similar biomolecules can be used as an earthquake sensor.

Keywords: Earthquake; Biotechnology; Nanotechnology; Geosciences; Earthquake measurements

Introduction

The paper presents an absolutely unique design approach for earthquake prediction with exact timing detail, using electrical behavior of bio-molecules and nanotechnology. Many attempts have been made till now to predict seismic events, but making a successful earthquake forecast is still a challenge before the scientific community. The studies carried out in the past using traditional seismological methods have solved the problem of long term prediction to a much extent [1]. However, the problem of short term prediction remains yet unsolved.

The main problem was to find a proper precursor. Precursory activities may include; Radon, Sulphur dioxide and helium emanation; Electromagnetic emissions; water level and temperature changes; ground uplift and tilt; the changes in ionospheric parameters, and so on. Among all earthquake precursors, those related to electromagnetic effects are the most important. The interest in electromagnetic phenomena caused by lithosphere and related to earthquake preparation increased considerably during the last years, and can be the most promising tools for earthquake prediction. Recent studies have shown that these pre-seismic electromagnetic emissions occur in wide frequency band, ranging from few mHz to few MHz. Such emissions have been found between Ultra Low Frequency (ULF) and High Frequency (HF) range. However, the frequency band in Ultra Low Frequency (ULF) range (0.0110 Hz) has been found to yield more reliable precursors, because of their large skin depth and low attenuation [2]. The ULF emissions can penetrate the crust and propagate through ionosphere and magnetosphere [3,4], hence are easily recorded by ground and space based systems. Moreover, these emissions occur few hours to few days before the main shock and their presence is felt even after main shock, for an inconsistent time period. Hence, these ULF/ELF emissions could be used as short term precursors in the area of earthquake prediction [4]. It has been found that seismic associated ULF emissions are accompanied by an additional signal, which differentiates them from nonseismic ones [1]. The unusual enhancement in magnetic field components, prior to seismicity has also been reported.

Organic sensor i.e. biomolecules such as hormones or enzymes are highly sensitive. It can respond to very low level of input at very low frequencies (around 10 Hz), as well as high frequencies (around 80-90 kHz) [5]. Norepinephrine (abbreviated norepi or NE) is a catecholamine with dual roles as a hormones and a neurotransmitter. Norepinephrine affects parts of the brain where responding actions are controlled [6-8]. Increase in blood pressure increases the pulse rate and the NE level, and increase in NE level raises the vibration sensitivity of the body. This behavior of NE can be exploited as biological vibration sensor. NE is a highly sensitive neurotransmitter, and if it would be used with corresponding receptor with proper interfacing electrodes, will act as a more efficient and powerful sensor than its inorganic counterpart [9,10].

Bio-molecular electrodes can be made with the help of nanotechnology [11-13]. Biomolecules and metallic or semiconductor nanoparticles (NPs) enable the synthesis of biomolecules–NP hybrid systems, where the unique electronic, photonic and catalytic properties of NPs are combined with the specific recognition and biocatalytic properties of biomolecules [12].

Objectives of the Concept

Our earth is on the verge of regular earthquakes/tsunamis because we are changing the moment of inertia of the earth, day by day by digging it as coal mines, metal mines, etc. and moving the inner crust mass to the surface of the Earth. Melting of ice due to global warming is adding the problem. Apart from all these, orientation of Jupiter, Saturn and disturbances in our Solar systems is another threat [14].

Issues Involved in Earthquake Detection

Input signals

Electrical signature: When a quake occurs, an electrical signature

***Corresponding author:** Awadhesh Kumar Singh, Maharaja Agrasen Institute of Technology, Rohini, Delhi-110086, India, Tel: +91-9811986037; E-mail: awadheshkumar_sngh@yahoo.co.in

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to the quake is produced by energy released from the fracturing rock. This electrical signature is radiated from the quake, and can be sensed by electric potential sensors. Of course, there are well-known ground waves that can be picked up in the traditional manner with seismographs. The problem with the ground waves is that when they arrive, the danger from the quake arrives. Picking up the electrical signature of the quake is the key for having additional seconds for warning [15].

Tests done on rock, creates balls-of-light coming out of the rock, and if it is crushed in a powerful hydraulic press it fractures the rock. The energy to create these balls-of-light comes from the energy released at the molecular level, when the rock fractures. The crystalline structure of most rocks would naturally align the atoms and molecules. This alignment would assist creating harmonic waves of energy. In other words, as the energy is released in various locations in the rock, because of the crystalline structure, the energy could align, thus facilitating the creation of balls-of-light and electrical signature.

Low frequency magnetic signals: Before major earthquakes, tiny and slow fluctuations in Earth's magnetic field have been recorded [10]. Before the quake, readings of Ultra Low-Frequency (ULF) magnetic signals (0.01-0.02 Hz) increases above normal levels, and then increases even higher on the day of the quake. The cause of these signals is electromagnetic energy released by electrons that are sheered from crystalline rocks, such as granite and a piezo-magnetic effect triggered by pressure applied to certain kinds of rocks [10,16].

Interferometry: Satellite-based methods that present as precursors to earthquake activity are Interferometric Synthetic Aperture Radar (InSAR). Basically in InSAR, two radar images of a given tectonic area are combined in a process called data fusion, and any changes in ground motion at the surface is thus detected [9,17].

Infrared radiation: One more idea is to look for surges in Infrared (IR) radiation. Just before the quake, thermal sensors detected temperature variations as large as 6°C to 9°C, according to Chinese documents. Satellites equipped with IR cameras can be used to detect these hot spots from space [16].

Release of SO_2: Sulphur dioxide is one of the main components of volcanic gases, and increasing amounts of it through fault line area indicates the arrival of quake. Most scientists believe that the change in gas levels is caused by the sealing of gas passages by hardened magma. Such an event leads to increased pressure in the volcano's plumbing system and an increased chance of an explosive eruption [14].

Analysis: Sensors based on SO_2 can predict earthquake, but in terms of weeks not in terms of exact time [18], so it is not suitable for a prediction system where high accuracy is required [14]. IR radiation from earthquake is also a good source of signal, but IR sensor based prediction system can predict earthquake in terms of week or at the most days, not with exact time details [16].

InSAR based prediction system depends on the changes in ground motion at the surface in the same tectonic area, so it can predict earthquake exactly when quake starts. Therefore, this system is also not efficient [9,17]. ULF magnetic signals are also good, but its correlation with biomolecules is not properly defined, otherwise it can also be taken as an input signal for the proposed bimolecular sensor [10,16]. Electrical behavior of NE in terms of its conductivity or impedance is well known. So, in this paper input signal is selected as mentioned in sub topic III (A), because the bio-molecular sensor can respond more effectively to this signal.

Measuring the Behavior of NE

Noradrenaline (NA) or Norepinephrine (NE)

NE is the next lower homolog of epinephrine. The two structures differ only in that epinephrine has a methyl group attached to its nitrogen, while the methyl group is replaced by a hydrogen atom in NE. Norepinephrine, (Figure 1), has a less bulky primary amine [7,8].

Spectrometry and binding of NE with its receptor

Basic experiments were performed to observe the change in transparency of NE and alpha-2 solution due to variation in its binding, in the presence of variable ELF magnetic field. It was observed that the opacity of the solution increases drastically with the increase in ELF magnetic field. It suggests that the change in ELF magnetic field increases the binding of NE with alpha-2 receptor (Table 1).

Voltammetry and measurements of NE behavior

Conjugation and interfacing of biomolecules and nanoparticles (NP): The similar dimensions of biomolecules and metallic or semiconductor Nanoparticles (NPs) enable the synthesis of biomolecules–NP hybrid systems. The aligned and reconstituted enzymes on the electrode surfaces reveal effective electrical contacting [11,12]. Toluene-filled nanotube film catalyzes the electrochemical response of biomolecules, such as Norepinephrine, while empty multi-wall carbon nanotube film shows no or less electro-catalytic behavior to these biomolecules. This suggests that filled nanotube have some particular properties compared to empty multi-wall carbon nanotube, and the development of filled nanotube is necessary. So, conjugation of toluene-filled CNT film with biomolecules as Norepinephrine, would be the best suitable sensor. This sensor responds to the generated electrical signature by the quake much faster than it's any other counterparts.

Another experiment performed was Voltammetry, measuring the current as a response to the applied potential. It was used to measure the response of NE [11,19]. The sensitivity and the selectivity are the crucial issues for the development of sensors, for detecting biologically important molecules. Conventional electrodes are not suitable for the determination of NE. The CNTs-modified electrodes had been used to resolve this problem. Modified Glassy Carbon Electrode (GCE) coated

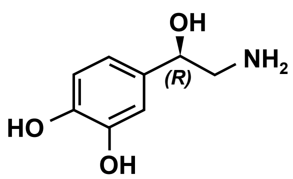

Figure 1: Molecular structure of Norepinephrine.

S.N.	Magnetic Field in gauss	Opacity in the scale of 20
1	1	1 almost transparent
2	2	2
3	3	4
4	4	6
5	5	9
6	6	11
7	7	13
8	8	16
9	9	20 translucent

Table 1: Magnetic field vs Opacity of NE/Alpha-2.

S.N.	Electric Field in micro-N/C	Approx. Current in micro ampere
1	10	40
2	20	50
3	30	60
4	40	70
5	50	80
6	60	90
7	70	100
8	80	120
9	90	140

Table 2: Electric Field Vs Current in Voltammeter.

with Nafion/SWCNTs for highly selective and sensitive determination of NE [13,20] (Table 2). The modified electrode enhanced the voltammetric signal of NE. Increase in electric field increases the immobilization of NE towards the electrode, which decreases the flow of current and was measured to be linear.

CNTs-modified electrodes have many advantages over other forms of carbon electrodes due to their small size, high electrical and thermal conductivity, high chemical stability, high mechanical strength and high specific surface area. Their small diameter and long length allow them to be plugged into NE with better electro-activity, compared to other carbon based electrodes. Analytical sensing at CNTs-modified electrodes results in low detection limits, high sensitivities, reduction of over potentials and resistance to surface fouling. The aforementioned outstanding properties of CNTs make them an exciting alternative for the development of novel electrochemical sensors and biosensors for earthquake measurements.

5 ml of purified NE is readily available in the market @ INR 500/- which is purchased for each experiment. It is used in the treatment of low BP patient.

Conclusions

Two experiments performed to study the behaviors of NE in the presence of electrical field, and in the presence of ELF magnetic field. Results of both the experiments suggest that NE can be used as a good biomolecular sensor to detect electrical and magnetic signals, as well. Therefore, this behavior of NE can be used to detect and predict the earthquake.

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