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On Reducing the Magnitude of an Impending Catastrophic Earthquake

Michael G. Noppe

Department of Applied and Theoretical Physics at NSTU (Retire), Kiryat-Yam, Israel
Email: noppe.mg@gmail.com

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Abstract

This article develops the ideas presented in the previous article, justifying the project proposed to determine the epicenter of a future short-focus earthquake tens of hours before the earthquake and the project to reduce the magnitude of an impending catastrophic earthquake. A physical and mathematical model of the prototype of a mercury earthquake precursor sensor is proposed, and the signal received by the old sensor is calculated. Analysis of an existing sensor prototype provides an understanding of physical processes and shows the fundamental advantage of the new sensor. An approach is formulated to explain the physical mechanism for reducing the magnitude of an impending catastrophic earthquake. A vibrator described in the literature is considered, the effectiveness of which for reducing the magnitude of future catastrophic short-focus earthquakes is estimated by the calculations of the long time of the earthquake precursor. The requirements for future specialized vibrators for the purpose of Reducing the Magnitude of an Impending Catastrophic Earthquake are formulated.

Keywords

Earthquakes Prediction, Physical Model, Earthquake Condition, Earthquake Precursor, Precursor Time Formula

1. Introduction

In July 2018, 30 short-focus weak earthquakes (with the hypocenter depths of 1 - 15 km) occurred in the region of Tiberias (Israel). According to the world classification [1], an earthquake with a magnitude of up to 5 is considered weak, a magnitude up to 7—average, and a magnitude above 7—strong or destructive.

In the near future, a global cataclysm may occur in the country, which will lead to the largest civilian casualties. Currently developed systems capable of predicting earthquakes for a sufficiently long period of time before it occurred have not yet achieved significant success (see Appendix 1). A new multi-year plan to protect the state from earthquakes was announced (Appendix 2). The prototype of the sensor patent [2] and article [3], based on measuring the flow of mercury vapor from the Earth into the atmosphere, are the basis of the projects described in [4]. In article [4], a physical model of the conditions necessary for the onset of an earthquake is presented, using a method based on recording flows of explosive gas rising from the Earth [5] [6] [7]. This model [4] explains the reason for the appearance of the precursor for a long period of time before the earthquake (from several hours to hundreds of hours) using a physical and mathematical model. Typical earthquake precursor times for seismic methods are tens of seconds (in Appendix 1). The formula for the time of the precursor of a future earthquake, obtained from the proposed physical and mathematical model of the earthquake, made it possible to explain and describe the increase in the time of occurrence of the precursor depending on the magnitude of the earthquake. The developed physical model of a short-focus earthquake is the basis for the proposed patent for determining the epicenter of a future short-focus earthquake dozens of hours before its start and for a project to reduce the power of an impending catastrophic earthquake.

This publication develops the ideas presented in the article [4]. A physical and mathematical model of the previous sensor of the mercury precursor of an earthquake is considered [3] and the signal received by the old sensor from the Earth and from the source of the earthquake is calculated (in Section 2). The specified calculation emphasizes the need and advantage of the new proposed sensor. An approach is formulated to explain the physical mechanism for reducing the magnitude of an impending catastrophic earthquake. Vibrators described in the literature are examined that best meet the requirements of a method for reducing the magnitude of future catastrophic short-focus earthquakes. A significant increase in the calculated time of occurrence of the earthquake precursor using a modern vibrator confirmed the effectiveness of the method for reducing the magnitude of future catastrophic short-focus earthquakes; requirements for future specialized vibrators are formulated for the purpose Reducing the Magnitude of an Impending Catastrophic Earthquake (in Section 3). Our proposals and Conclusions are presented in Section 4 and Section 5.

2. Physico-Mathematical Model of the Prototype of a Mercury Precursor Earthquake Sensor

2.1. Information on the Use of Mercury Flux Measurements as Earthquake Precursors

An increase in Hg mercury gas was recorded in the Tashkent region after the 1966 earthquake, and it has been suggested that Hg may be a harbinger of an earthquake [8]. In Russia, equipment and methods for measuring mercury gas to determine information about a future earthquake have been developed since

1968 [8]. In [3], based on work in China, it was concluded that mercury anomalies are the best harbinger of earthquakes. The triumph of the program in China was the prediction of the February 4, 1975 earthquake and the rescue of more than 20,000 people. The article [3] and the patent [2] describe the invention of a method for predicting earthquakes in seismically active regions, based on recording the density of the flux of mercury vapor from the Earth into the atmosphere, which is the geochemical precursor of earthquakes and is the prototype for our future work. The inventive periodically records the precursor of an earthquake (flux density of mercury in a gas rising from the Earth), then you can predict the possibility of an earthquake based on an abnormal change. The value of the flux density is recorded over time. The empirical data accumulated during monitoring at the observation point suggest that the content of mercury vapor in a closed cavity inside the loose layers can vary with increased amplitude (10 - 1000 times) over the course of only a few hours, which correlates with subsequent earthquakes. The accumulated data show that an earthquake is preceded by the appearance of a precursor, which is manifested in a short-term increase in the mercury content in the gas contained in the chamber 4 - 40 hours before the earthquake. In addition, there are positive correlations between the amplitude of the precursor, the magnitude of the earthquake, and the length of the period between the appearance of the precursor and the moment of the earthquake. Depending on the magnitude, such precursors can be detected at a distance of 100 km or more from the sources of the earthquake [3]. The insert in **Figure 1** (from Figure 2 in [2]) represents the measurement of mercury flux density prior to the October 29, 1983 earthquake in Dushanbe, 37 hours before the earthquake.

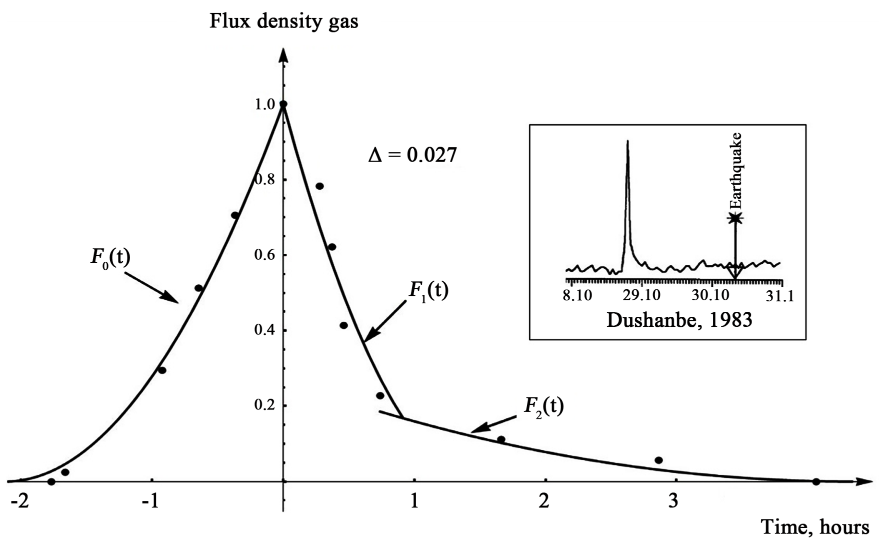

Figure 1. Measurement of the flux density of mercury before the October 29, 1983 earthquake in Dushanbe in the insert (from Figure 2 in [2]) and the results of calculating the signals received by the prototype sensor from the Earth and from the source of earthquakes (in Subsection 2.2).

2.2. Physico-Mathematical Model of the Prototype of a Mercury Precursor Earthquake Sensor

The delta-shaped appearance of increased pressure in the earthquake source leads to the appearance of a pressure filtering wave propagating in all directions, and, accordingly, to a measurement point on the Earth's surface (pressure filtering waves have long been known and, in particular, have been used to study formation parameters [9]). To simulate the signals received by the prototype sensor from the Earth and from the source of the earthquake, we use the theory of propagation of intense acoustic waves in a medium without dispersion. In §3, chapter 6, in [10] the problem of changing the amplitude and duration of a single triangular perturbation is described, described by the following expression for the initial form of perturbation

$$u(\tau)/u_0 = \{0, \text{for } \tau < 0; (1-\tau/T_1), \text{for } 0 \le \tau \le T_1; 0, \text{for } \tau > 0\} \tag{1}$$

where u is the vibrational velocity, T is the pulse duration. Formulas describing the change in the peak value of the vibrational velocity $u_2(r)$ and the pulse duration $T(r)$ have the form

$$u_2(r) = u_0(1+ar)^{-1/2}; \; T(r) = T_1(1+ar)^{1/2} \tag{2}$$

where r is distance, $a = \varepsilon u_0 / c^2 T_{11}$, $\varepsilon = (\gamma+1)/2$, γ is the adiabatic index of the medium, c is the speed of the acoustic wave. Based on formulas (2), we write down the formulas used, into which we decompose the experimental curves of the mercury vapor flux density in the old sensor [2] (see the inset in **Figure 1**) into three functions $F_0(t)$, $F_1(t)$, $F_2(t)$, depending on four parameters, T_{10}, T_{11}, T_2, t_3.

$$F_0(t) = F_{00}(1+t/T_{10}), \; -T_{10} \le t \le 0 \tag{3}$$

$$F_1(t) = F_{00}(1-t/T_{11}), \; 0 \le t \le T_{11} \tag{4}$$

$$F_2(t) = F_{00}\left[1-(t-t_3)/T_2\right]^2 / (T_{11}/T_2)^2, \; t_3 = r/c, t_3 \le t \le T_2 + t_3. \tag{5}$$

where T_{10}, T_{11}, T_2, t_3 are the parameters that are selected while minimizing the least squares function. Given that the ordinate axis is not shown in the experimental chart, we will take $F_{00} = 1$. The function Δ was chosen as the minimized function of the least squares method

$$\Delta = \sum_{i=1}^{3} \sum_{l=k}^{j} \left(F_i(t_l) - XY_l\right)^2 \tag{6}$$

where XY_l are the experimental data, shown by round dots in **Figure 1**, XY_l were taken from the experimental function shown in the inset in **Figure 1**. As a result of minimizing the function Δ, the parameters were determined T_{10} = 2.12, T_{11} = 1.55, T_2 = 3.6, t_3 = 0.74 (hours) and $\Delta = 0.027$. Thus, using the mathematical model, we were able to decompose the signal received by the sensor into 2 signals, represented by lines in **Figure 1**, which we will interpret as follows: 1st signal ($F_0(t)$ and $F_1(t)$), which comes in sensor perpendicular from the Earth; 2nd signal $F_2(t)$, which comes from the source of the earthquake to the sensor. It has been established that the value of the upward flow of mercury vapor in the gas rising from the earth's crust is determined by the degassing of the earth's crust [5] [6] [7], as well as mechanical stresses and deformations of rocks at the measurement point [2]. Thus, the release of mercury vapor from rocks during their deformation is used in sensors [2], whose signals we decomposed using Formulas (3)-(5) and this decomposition is shown in **Figure 1**.

2.3. Proposed Patent for Determining the Epicenter of a Future Short-Focus Earthquake

In [3] and in patent [2] the invention of the method of earthquake prediction was described, which is the prototype of our future work. Summary of the analysis of the prototype: examples of determining the hypocenter and epicenter were based on the empirical Formula (2) in [3], which uniquely describes only earthquakes with a magnitude of $M > 5.5$, the physical justification of Formula (2) in [3] is not presented. The patent [2] describes an invented method for predicting earthquakes in seismically active regions based on spatio-temporal changes in the density of mercury vapor flux from the Earth to the atmosphere, which is the geochemical precursor of earthquakes. The invention consists in conducting periodic registration of an earthquake precursor in a given control zone. For this, the density of mercury is recorded in the gas flow ascending from the Earth at a depth of not less than 1 m. Then, according to the abnormal change in density over time, the possibility of an earthquake can be predicted. In the described patent, the flow of mercury can come from any direction into one sensor, information about the angle of direction from which the stream came is lost. For example, in **Figure 1**, after filling the trap, the gas diffuses from the traps, but information about the direction from which the gas flow entered the measuring device is not recorded. The prototype assumes that the directions from which the flow from the trap into the measuring device came from can be found by Formula (2) from [3], which does not describe the situation with high accuracy. In our proposed patent [4], the flow of mercury from any direction of a certain solid angle Ω enters only one sensor. The number of sensors located in the hemisphere is $N = 2\pi/\Omega$. Thus, as soon as the delta-shaped gas flow from the fault fills all the traps in the region, the gas begins to diffuse in all directions from all the traps in the region. Now, analyzing the gas flows in the entire set of sensors in the hemisphere, we can immediately determine the sensor with the maximum gas flow from all traps in the region and find the solid angle from which the maximum gas flow arrives at each station from all earthquakes. Considering together the maximum gas flows from several stations located in the region, we can determine the epicenters and hypocenters of future earthquakes. Signal $F_2(t)$ comes from the earthquake source to the sensor. The magnitude of the signal was calculated and $F_2(t)$ is represented by Formula (5), but the information about the angle Ω disappears in the prototype, in contrast to the proposed new sensor, in which Ω is simply determined, which allows determining the epicenters and hypocenters of future earthquakes.

3. The Decrease of Magnitude of the Impending Catastrophic Earthquake

1) This subsection describes a decrease in the magnitude of a future earthquake, based on the article [11]. Studies of excited seismicity in the area of the dam reservoir of the Nurek hydroelectric station showed that with an increase in the level of vibrations during spillways, the average daily released seismic energy normalized to an area of 1000 km^2 decreases by 3 orders of magnitude and strong earthquakes disappear. **Figure 2** shows that with an increase in the vibration level from 0.02 μm (the natural level of microseisms) to 0.4 μm, the average daily released seismic energy normalized to an area of 1000 km^2 decreases by 3 orders of magnitude. In separate periods of time, when the amplitudes of technogenic vibrations in the adjacent territories reached a maximum value of 0.5 μm, earthquakes completely disappeared.

2) Our approach to explaining the physical mechanism for reducing the magnitude of an impending catastrophic earthquake (another interpretation was given in [11]) is that the effect of vibration leads to an increase in gas pressure in the centers for earthquakes, which should lead to a violation of the necessary earthquake conditions [4], which will significantly increase the time of the earthquake precursor T_1. Two chemical reactions ((7) and (8)) in the centers for earthquakes, which are described below, also favor the increase in the time of the T_1 earthquake precursor. Under conditions of oxygen deficiency, all hydrocarbons emit carbon dioxide and water. For example:

$$CH_4 + 3O_2 = CO_2 + 2H_2O \tag{7}$$

With even less oxygen, carbon (soot) is released:

$$CH_4 + O_2 = C + 2H_2O \tag{8}$$

For an earthquake to occur, oxygen is needed in its focus. Therefore, the more time elapses from the moment the trap is filled with gas, the less oxygen is present in the focus due to reactions (7), (8), which ultimately leads to an increase in the precursor time and, consequently, to a decrease in the magnitude of

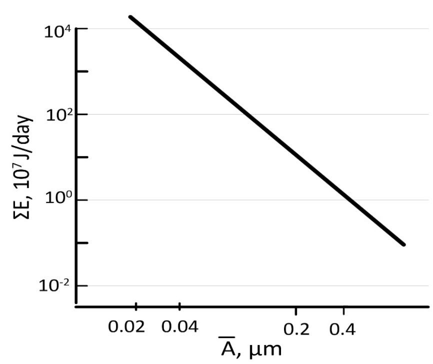

Figure 2. The graph of the average daily released earthquake energy per unit area of 1000 km^2 in the water area of the Nurek hydroelectric power station depending on the level of microseisms at different distances and at different time periods for gradually receding zones within a radius of up to 25 km from the spillway (from [11]).

the earthquake. Based on the derivation of the formula for the earthquake precursor T in Section 5 of article [4], we write the earthquake precursor T_1, when the vibrating device creates an oscillation with amplitude a and frequency ω

$$T_1/T = 1\Big/\left(1 - ac_0\right)^{2/3}, \text{ where } c_0 = \omega\rho\mu_0 c\Big/\left(\sqrt{2}k_B T_k U_1\right) \tag{9}$$

Consider a 40-ton CV-40 mobile vibrator designed for deep seismic sensing to a depth of 50 km [12]. The working range of the probing signals from the CV-40 vibrator was 8 - 11.23 Hz. Using (9), we calculate c_0

$$c_0 = \omega\rho\mu_0 c\Big/\left(\sqrt{2}k_B T_k U_1\right) = 0.171929\left(1/\mu\text{m}\right) \tag{10}$$

where frequency of the vibrator is $\omega = 2\pi \times 11.23\ \text{Hz}$; density is ρ = 5000 (kg/m^3); molecular mass of CH_4 is μ_0 = 2.663 × 10^{-26} kg; speed is c = 8000 (m/s); Boltzmann constant is k_B = 1.38 × 10^{-23} (J/K); temperature is T_k = 280 K; U_1 is the gas density at which an earthquake occurs, for example, (for CH_4 and air) U_1 = 0.08 (kg/m^3) from [4]. Using (9) and (10), we present in **Figure 3** the dependence of (T_1/T) on amplitude a. The article [12] presents displacements from the CV-40 vibrator at a distance of 0.6 km: a_x = 4.3 μm, a_y = 1.5 μm, a_z = 3.3 μm. Thus, the use of a sufficiently powerful vibrator should violate the necessary earthquake conditions, which will increase the time of the T_1 earthquake precursor, which will ultimately lead to a decrease in the magnitude of the impending catastrophic short-focus earthquake.

Consider the Prospects for the Development of Vibrators to Lower the Magnitude of Future Earthquakes

"In seismic exploration, two types of complex signals are used:

- the so-called quasi-harmonic complex signals, *i.e.* harmonic signals with a changing frequency;
- code-pulse signals, *i.e.* a sequence of pulses following a specific code.

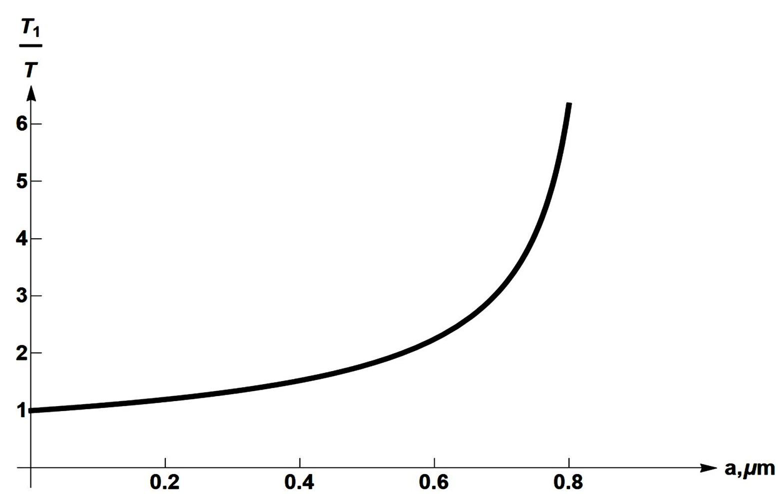

Figure 3. The ratio of the time of the earthquake precursor T_1 when the vibrator creates oscillations to the time T of the earthquake precursor when the vibroseismic device is absent.

Complex signals are rather broadband and quite extended signals, therefore, even if the emitter excites relatively small-amplitude oscillations compared to powerful pulsed emitters, for example, within the limits of elastic deformations of the soil, the total energy of the generated sweeps can be arbitrarily large depending on the length signal. Currently, the durations of complex signals used in seismic surveys are usually 10 to 30 seconds." [13].

We formulate the primary requirements for the vibrators needed for the emerging direction of Reducing the Magnitude of an Impending Catastrophic Earthquake (rather than vibratory seismic).

Thus, it is proposed to create vibrators:

- which create complex signals with a duration of more than 30 seconds, in order to increase the power of the signals,
- which are working at the required depth,
- to study vibrators using code-pulse signals, which are several times cheaper than vibrators using quasi-harmonic complex signals.

Vibrational seismic acquisition, which has accumulated gigantic scientific and technical potential, is naturally the basis for creating vibrators to solve a new goal. We list some of the vibrators that can serve as the basis for the creation of new emitters: "GSV-100, CV-100, NCV, CVA, GRV-50 and GRV-200 stationary vibrators with a vibrational force on the ground of 500 - 2000 kN and a mobile vibrator CV-40 with a force of 400 kN were developed at the SB RAS to ensure the depth of vibroseismic transillumination at least to the bottom of the earth's crust (40 - 50 km) and to achieve a sensing range of up to 1000 km and above. According to theoretical calculations, a vibrator with an amplitude of disturbing force of at least 100 ton-forces in the frequency range of 2 - 15 Hz was required" [14]. "To increase the radiation power, experiments were started according to the grouping of powerful vibrators. At a number of points, the sources were located close to the distances between them from 1 to 3 m. When the vibrators become in resonance, the radiation amplitude increases by 1.2 - 2 times compared to the work single vibrators" [15]. "Vibrators using code-pulse signals are simpler and several times cheaper than vibrators using quasi-harmonic complex signals. Therefore, in order to reduce cost, it is necessary to consider the creation of vibrators that create code-pulse signals". "In the early eighties in the association 'Potential' (Kharkov) was mastered the serial production of code-pulse emitters IKI-10/40. But then, for a number of reasons, the manufacturer stopped the production of emitters creating code-pulse signals." [13].

4. Our Proposals

1) A patent is proposed for a new device for recording information about earthquake precursors using mercury measurements as an extremely strong and sensitive forerunner occurring tens of hours before an earthquake. The proposed equipment for recording information should be able to determine the epicenter of a future earthquake.

2) It is proposed to create a network of stations in the north of Israel. At each

station it is proposed to place a device for determining the epicenter of a future earthquake.

3) Observational materials [16] indicate the possibility of considering CYCLONS of atmospheric pressure as trigger effects on large earthquakes. The atmospheric pressure gradients for 42 earthquakes are shown in **Table 1** and in **Figure 4**.

Thus, the origin of thirty earthquakes in July 2018 may be associated precisely with the preceding negative gradients of atmospheric pressure in the Tiberias region [4]. Note, that the overwhelming number of earthquakes in Israel occurred precisely in the summer months, when quiet weather with warm temperatures is usually observed [1]: July 11, 1927, August 3, 1993, June 2004, June 12, 2008, July 13, 2008, July 15, 2008, April 17, 2009, April 12, 2010, March 9, 2010, March 20, 2010, July 15, 2010, August 23, 2010.

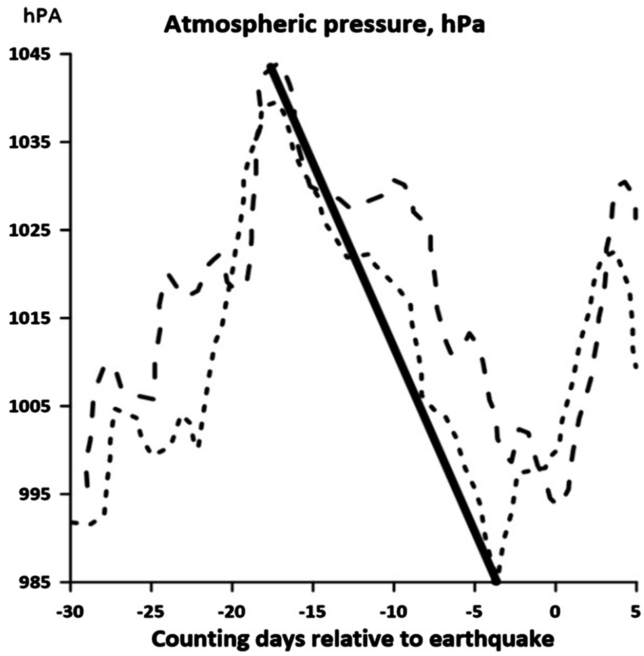

Figure 4. An example of atmospheric gradients pressure before an earthquake (depending on the number of days relative to an earthquake) with $M \geq 7.5$, registered on the 2 closest to the epicenter of observation points. 11/16/2003. $M = 7.8$ Rat Islands (Aleutian Islands), Alaska. **Figure 4** is given in [16]. **Figure 4** shows the graphs for atmospheric pressure 30 days before and 5 days after the earthquake that occurred during a cyclone.

Table 1. Atmospheric pressure gradient distribution for earthquakes with $M \geq 7.5$.

Gradient amplitude (mm Hg. St)	N earthquakes
4 - 10	24
10 - 20	9
>20	9

4) It is proposed to create device for determining the dependence of air pressure on time in stations of network.

5) Having determined the epicenters of a future earthquake, in which very large mercury gas flows are measured (and, therefore, the appearance of large future earthquakes can be assumed), it is proposed to use vibrators CV-40. In addition, it is necessary to notify the population of the expected future earthquake.

6) It is proposed to increase the radiation power, grouping powerful vibrators.

7) It is proposed to expand the work on creating specialized vibrators, which will be more powerful and cheaper, for the purpose of Reducing the Magnitude of an Impending Catastrophic Earthquake.

5. Conclusion

The previously presented physical model of the conditions necessary for the onset of an earthquake, described for a method based on the registration of mercury vapor flows in a gas rising from the Earth. This model explains why the precursor appears for such a long period of time before an earthquake (from several hours to hundreds of hours) using a physical and mathematical model. This article develops a physical and mathematical model of the previous mercury earthquake precursor sensor and calculates the signal received by the old sensor. A review of the previous sensor provides the rationale for creating a new sensor. A modern CV-40 vibrator is considered, the effectiveness of which is estimated by calculating the long time of the earthquake precursor (see **Figure 3**), which ultimately should save the lives of citizens, property and infrastructure from future short-focus earthquakes. This article defines the requirements for specialized vibrators for the purpose of Reducing the Magnitude of an Impending Catastrophic Earthquake. Thus, for the emerging direction of Reducing the Magnitude of an Impending Catastrophic Earthquake (rather than vibrational seismic exploration), it is necessary to create vibrators that create complex signals with a duration of more than 30 seconds, in order to increase the power of signals and vibrators that use code-pulse signals, which are several times cheaper vibrators using quasi-harmonic complex signals. Creation and research of vibrators for the purpose of Reducing the Magnitude of an Impending Catastrophic Earthquake; theoretical modeling of chemical processes (7)-(8); modeling the influence of atmospheric pressure; should be the next stage of research of the developing direction.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix 1

The Canadian company "Nanometrix" offered an earthquake early warning system; this technology will allow to be informed about an earthquake with an interval of 10-30 seconds between the first strong earthquake and the destructive wave following it [17]. In addition, the Geological Survey of Israel (GSI) is developing a system called "Troy" ("Trumpet Sound"). According to information received from the head of this seismological project, when the alarm signals are heard, tremors will already be felt in Tiberias if the epicenter is in the Kinneret area [18]. Thus, attempts to find and implement a system capable of predicting earthquakes over a sufficiently long period of time before an earthquake have not yet achieved significant success.

Appendix 2

The Minister of Defense announced (07/05/2018) that a new multi-year plan to protect the State of Israel from earthquakes will be presented to members of the government. The Minister of Defense specified that the plan will be more focused on the northern regions of the country, in which seismic activity is higher [19].