

# Environmental Infrasound Pollution and Its Effects on Human Populations

*Postulating a new dimension for interpretation and alleviation of global terrorism*

R. Gopalaswami\*

Former Chairman & Managing Director, Bharat Dynamics Ltd. Hyderabad

\*Corresponding author: [gopalaswami@gmail.com](mailto:gopalaswami@gmail.com)

**Abstract** Infrasound is very low frequency acoustic wave with frequencies ranging from 0.01Hz to 20 Hz. Environmental infrasound emanates from earthquakes, mountain valleys, volcanoes, coal mines, atmospheric wind turbulence, and oceans. Man-made infrasound is from transportation and industrial systems. Scientific evidence has established that infrasound can be very harmful and indeed dangerous to human life. Studies worldwide reveal that regions of high seismicity are also locations of high environmental infrasound. “Hot spots” of high seismicity in West, Central and South Asia particularly in the region within the boundary of colliding tectonic plates at 34°N latitude are also seen to be regions of ethnic conflict and hotbeds of terrorism. This paper proposes a hypothesis that among the many potential sociological, biological and geopolitical causes of anti-social and violent behavior in human populations, environmental emissions of infrasound is identified as a potential harmful factor. *The findings of scientific* studies are presented on infrasound science and technology; infrasound toxicology research; sociology; geology and geophysics and analysed for correlations. The need for experimental verification of this hypothesis at least in such ‘hot spot’ regions is paramount. Considerable research has already been carried out on harmful effects of infrasound but focused on individuals. Very preliminary studies on effect of infrasound in a large assembly of people (about 750) indicate that about 20% of the population alone is harmed. New infrasound-cancellation technologies are proposed to alleviate the harmful effects of environmental infrasound pollution. Widespread experimental studies would provide better understanding of environmental infrasound and could well usher in a new era of world peace.

**Keywords:** *plate tectonics, environmental infrasound, seismicity, ethnic conflict, electroacoustics*

**Cite This Article:** R. Gopalaswami, “Environmental Infrasound Pollution and Its Effects on Human Populations.” *Journal of Environment Pollution and Human Health*, vol. 5, no. 3 (2017): 93-98. doi: 10.12691/jephh-5-3-3.

## 1. Introduction

Infrasound is very low frequency acoustic wave with frequencies ranging from 0.01 to 20 Hz. It is generated by natural sources such as earthquakes (1Hz to 12 Hz), cyclones (> 10 Hz; up to 135 db at 100 km/h), thunder, volcanoes etc. For many decades infrasound was believed to be inaudible. However recent (2015) research indicates that contrary to belief that infrasonic noise and some low-frequency noise are inaudible it has been established that hearing does not stop at 20Hz, as humans can hear infrasound up to 1Hz [1].

Studies have been carried out on emissions of infrasound in the epicenter zone of earthquakes [2]. Infrasound emissions are also due to rock fracture [3] where the characteristic frequencies typically range from about 2.0 to 8.0 Hz for different kinds of rocks; from volcanoes where the lava tube system near a vent complex emits almost continuous infrasound generally in the 0.3-10 Hz frequency range [4]. Infrasound is also generated by trucks, cars, air and rail traffic, heavy machinery etc. Wind turbulence in

mountainous regions generates infrasound where it can cause an adverse effect on aviation. At Boulder in Colorado, USA, air accident rates rose by 40% over national average, where mid-day infrasonic signals were recorded every half an hour [5] established as due to mountain clear air turbulence. Windmills are also a source of infrasound due to turbulent air flow past its blades and its rotating machinery, where it was found to be an annoyance to technicians working in close proximity to a large-scale wind farm [6].

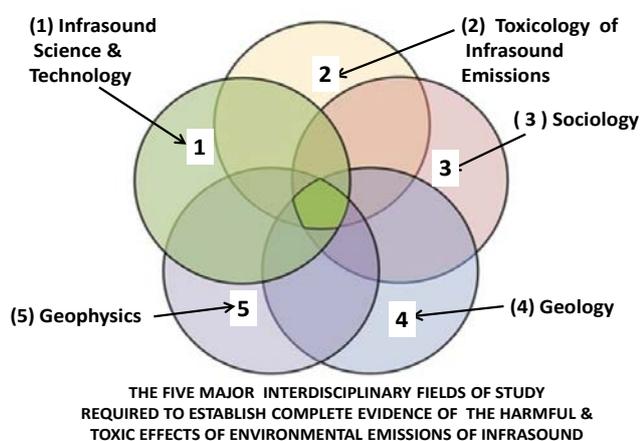
This paper proposes a hypothesis that among the many potential sociological, biological and geopolitical causes of anti-social and violent behavior in human populations, emissions of environmental infrasound is identified as a potential harmful factor perhaps at the hard core of health and behavioural problems in such locations. This is based on review of extensive evidence from specialized studies in the areas of infrasound science and technology; infrasound toxicology research; sociology; geology and geophysics. In the concluding paragraphs, it is recommended that such a highly inter-disciplinary and inter-agency experimental study needs to be carried out to understand and establish the exact correlation between infrasound and human behavior.

## 2. Methodology

The approach to develop this hypothesis is to find answers to the question: “Can environmental infrasound have an adverse effect on human health and behavior?” The answer to this question lies in correlating five overlapping knowledge domains (Figure 1), which are:

1. Infrasound science and technology,
2. Infrasound toxicology research
3. Sociology
4. Geology and
5. Geophysics.

A detailed literature search of the above domains is carried out and presented here as tangible evidence for the proposed hypothesis. A correlation is also attempted to link regions of high levels of potential infrasound with anomalous human behavior in the affected regions.



**Figure 1.** Five Major Interdisciplinary Fields of Study Underlying this Research Hypothesis

## 3. Infrasound Science and Technology

**Sources of Infrasound:** Infrasound is an inaudible signal that is not absorbed easily by water or air, and propagates over large distances because of its long wavelength. Infrasound exposure is ubiquitous in modern life. Infrasound is generated by

1. Natural sources such as earthquakes (about 1Hz to 12 Hz in the epicenter region) thunder, large waterfalls, ocean waves (< 1 Hz), wind (up to 135 db at 100 km/h; up to 110 db at 25 km/h); fluctuations in atmospheric pressure (< 1 Hz at 100 db), and volcanoes
2. Means of transportation such as automobiles, trucks, aircraft, watercraft, and rail traffic (1-20Hz at 110db)
3. Certain therapeutic devices (which do not meet the restriction of infrasound to airborne delivery), 4 Hz
4. Numerous industrial sources such as heavy machinery and air compressors; air heating and cooling equipment
5. Household appliances such as washing machines.

### Infrasound Measurements Used to Predict Earthquakes [7]

Scientists are trying to incorporate multi-disciplinary precursors to forecast earthquakes on a short-term basis. They have analyzed Outgoing Long-wave Radiations

(OLR) obtained by polar-orbiting National Oceanic and Atmospheric Administration (NOAA) satellites, and long-period infrasound waves recorded by the ground observatories in China prior to the recent earthquake at Bonin Islands, Japan on May 30, 2015 with a Richter magnitude of 7.8. While the OLR was recorded on May 15, 2015, an abnormal infrasound spike was recorded at the Beijing station on May 17, 2015. The delay in observing anomalous infrasound waves compared to the OLR anomaly is due to these low-frequency waves traveling at low speed (10-15 m/s). It can be inferred that there is a correlation between OLR and infrasound.

### Detecting Volcanic Activity [3]

Infrasound measurements are carried out to detect volcanic activity and even falling meteors. For example, infrasonic array data collected at K’lauea Volcano, Hawai’i, during November 12-21, 2002 indicate that the active vents and lava tube system near the P’u ‘Oo vent complex emit almost continuous infrasound in the 0.3–10 Hz frequency band. The infrasonic component of the experiment that consisted of a four-element infrasonic array at a range of 2 km from the active vents and two thermal and infrasonic channels at a range of 100 m from the active vents. On the last day of the experiment, a very small aperture array was deployed 13 km from the vent. Thus, by using sophisticated infrasound measurement techniques, scientists have demonstrated that it is feasible to identify regions and causes of environmental infrasound emissions.

## 4. Infrasound Toxicology Research

Exposure of humans to infrasound at specific frequencies, amplitudes and durations are responsible for harmful effects like sustained annoyance and irritation [8] and aversion to live in the locality [9]. A possible correlation between this aversion to live in regions of environmental infrasound and early population migrations from Central Asia (Fergana Valley) cannot be answered without gathering extensive evidences over a millennium. One is not sure about the availability and veracity of seismic data over such an extended time period.

Sleep disorders [10] were noted when exposed to infrasound of 6 and 16 Hz at 10 db. The effects of long-term exposure to infrasound were studied in 40 active Swiss Air Force pilots who were exposed to infrasound of 14 or 16 Hz at 125 db. Somatic and psychic functions were affected in the following ways: decrease in systolic blood pressure, increase in heart rate and blood pressure, impaired alertness and altered hearing threshold and time perception [11].

The findings of Gavreau [12] in the infrasonic range between 1 and 10 Hz are truly unnerving. They include lethal infrasonic pitch lies in the 7 Hz range; small amplitude increases affect human behavior in this pitch range; intellectual activity is first inhibited, blocked, and then destroyed; as the amplitude is increased, several disconcerting responses have been noted. These responses begin as neurological interferences; the action of the medulla is physiologically blocked, its autonomic functions cease. It is also to be noted that in World War II, Nazi engineers used infrasound to stir up hostilities of crowds gathered.

## 5. Sociological Effects

Considerable research has been carried out on harmful effects of infrasound but focused on individuals and collectives of about 40 selected people at the most. Very little work is published on effect of infrasound exposure on large population. One news article from a very reputed news source (Reuters) brings out a single experiment in 2003 involving 750 people exposed randomly to brief infrasound episodes in between normal musical sounds from an orchestra that could mask other pleasant musical sounds. It is recorded that 22% of the population reported discomfort and uneasiness during whenever the random exposures to infrasound emissions took place. The details of the experiment are copyrighted [13].

The difficulties of getting reliable data on effects of infrasound on a sociological level are seen from abstracts of published papers in this area. It is reported that [14] *“The greatest source of variance in human studies is individual differences. Different people can respond, if at all, quite differently to the “same” physical stimulus. Complex partial seizures, in particular, can be evoked by specific smells, musical cords, and even word sequences. The etiology for the hypersensitivity to very low levels of energy with a particular spatial or temporal pattern is related to an often subtle physical characteristic within the microstructure or chemistry of the person’s brain. Appreciation for the importance of individual differences and vulnerabilities when considering the effects of infrasound cannot be overemphasized.”*

### Effects of Low Frequency Noise in daily life [15]

From other abstracts of published scientific papers, it is seen that *“a systematic review of observational studies was conducted to assess the association between everyday life low-frequency noise (LFN) components, including infrasound and health effects in the general population. Literature databases Pubmed, Embase and PsycInfo and additional bibliographic sources such as reference sections of key publications and journal databases were searched for peer-reviewed studies published from 2000 to 2015. Seven studies met the inclusion criteria. Most of them examined subjective annoyance as primary outcome. Some associations were observed between exposure to LFN (infrasound) and annoyance, sleep-related problems, concentration difficulties and headache in the adult population living in the vicinity of a range of LFN sources. However, evidence, especially in relation to chronic medical conditions, was very limited. The estimated pooled prevalence of high subjective annoyance attributed to LFN was about 10%. Epidemiological research on LFN and health effects is scarce and suffers from methodological shortcomings. Low frequency noise in the everyday environment constitutes an issue that requires more research attention, particularly for people living in the vicinity of relevant sources”*. Hence it can be tentatively stated that about 10-22% of a population are adversely affected by exposure to infrasound.

### Correlation between Seismicity, Infrasound and Social Conflict

Two regions in India are identified for this study where the terrain, soil characteristics and geology suggest possibility of infrasound emissions. North-eastern India is also a region of high seismicity in India and at the

boundary of colliding Indian and Eurasian tectonic plates. Seismic simulation studies in north-east regions of India have already brought out that dominant frequency of vibrations of the soil in the Guwahati region are in the infrasound region [16]. Here too, one has historically witnessed population migrations from mountainous regions of South-East Asia.

Northern Kashmir appears to have been repeatedly and severely affected by most of the earthquakes. The slow-motion of tectonic plate collision has created one of the most active “earthquake hotspots”. However, no attempt so far has been made to correlate these earthquake/volcanic “hotspots” with “infrasound hotspots”. The Kashmir Valley is a mountainous rectangular U-shaped region. It has been modeled as a rectangular cavity and its atmospheric resonant frequency is estimated by the Helmholtz equation at 0.12 Hz in 1D mode and 0.04Hz in 3D mode. These frequencies lie in the infrasound region [17].

On October 8, 2005, one of the geological faults underlying Kashmir gave way, resulting in a Richter magnitude of 7.6 earthquake which killed more than 80,000 people, while an estimated 4 million were left homeless. Massive fissures and rock fractures occurred that have the potential to release high intensity infrasound. Normally large-scale natural disasters do tend to have an impact, directly or indirectly on geo-politics. However, unlike earthquakes in Turkey and Indonesia that brought peace to the regions, the response in Kashmir has been just the opposite [18]. After the 2005 earthquake, conflict there has escalated. *Needless to point out that multiple sociological, biological and geopolitical factors also exist that may drive/amplify such harmful effects on human life not just due to exposure to infrasound.* But without scientific measurements it cannot be established that there were no infrasound emissions in earthquakes in Turkey and Indonesia; or that the sustained disorder and violence in Kashmir is the outcome of environmental sources of infrasound being amplified by the geo-acoustics of the size and shape of the Valley and its soil characteristics. Experimental studies in environmental infrasound emissions are needed to provide definitive evidence to correlate human health and anomalous behavior in these regions and other geologically similar regions in the world.

## 6. Geology & Geophysics

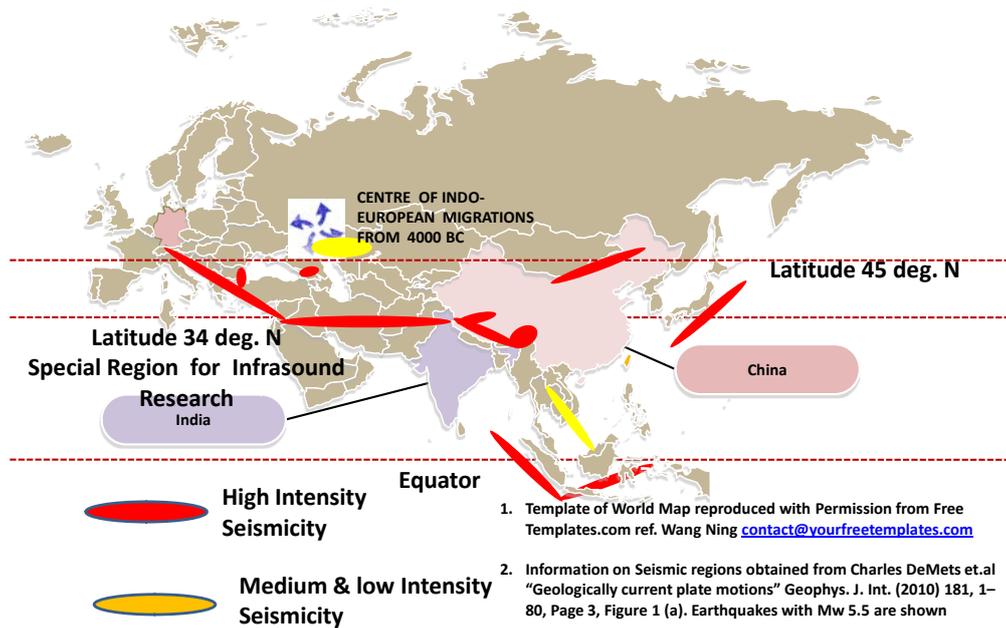
### Tectonic Plate Movements and Potential Environmental Infrasound Locations in Central, West and South Asia

The concept of plate tectonics was formulated in the 1960s. According to the theory, Earth has a rigid outer layer, known as the lithosphere, which is typically about 100 km (60 miles) thick and overlies a plastic layer called the asthenosphere. The lithosphere is broken up into about a dozen large plates and several small ones. These plates move relative to each other, typically at rates of 5 to 10 cm (2 to 4 inches) per year, and interact along their boundaries, where they converge, diverge, or slip past one another. Such interactions are thought to be responsible for most of Earth’s seismic and volcanic activity, although earthquakes and volcanoes are not wholly absent in plate interiors. Plate motions cause mountains to move up where plates push together, or converge; continents

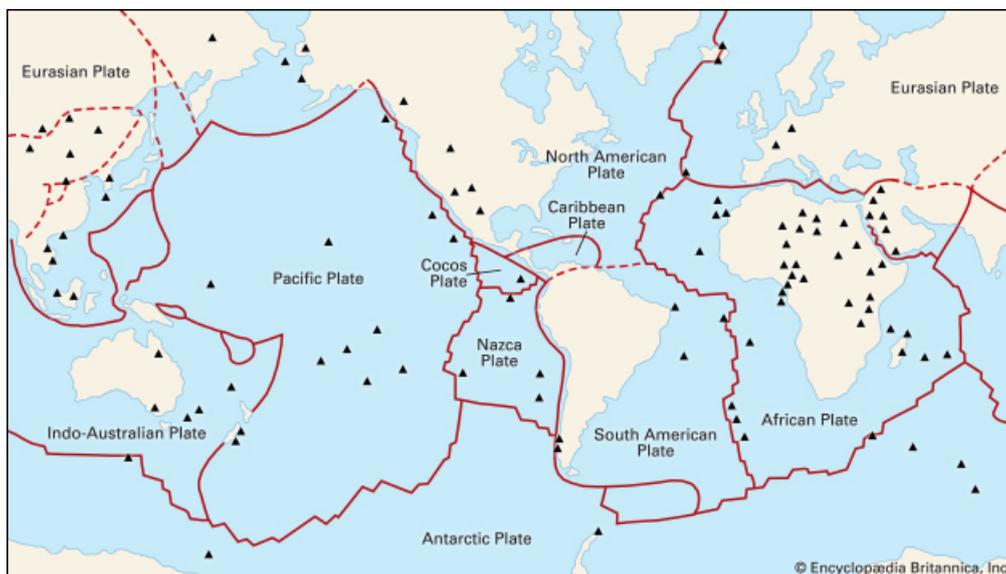
fracture and oceans form where plates pull apart, or diverge. The continents are embedded in the plates and drift passively with them, which *over millions of years* results in significant changes in Earth's geography. The northward movement of the Indian tectonic plate led to collision with Asia some 40 million years ago. Since that time India has advanced a further 2,000 km (1,250 miles) beneath Asia, pushing up the Himalayas and forming the Plateau of Tibet. Pinned against stable Siberia, China and Indochina were pushed sideways, resulting in strong seismic activity thousands of kilometres from the site of the continental collision [19].

Since infrasound is associated with earthquakes and volcanic activity, due attention is given to regions of high

seismicity worldwide. The specific focus of this study however is on Asia along boundaries of the Indian and Arabian tectonic plates (between 15°N and 45°N latitudes) [20] as shown in Figure 2. The boundaries of major tectonic plates constituting the Earth's lithosphere are shown in Figure 3 that includes submerged and exposed volcanic 'Hot Spots' along the dotted lines where infrasound emissions may exist. The number of these Hot Spots [21] is uncertain (estimates range from 20 to 120), but most occur *within a plate* rather than at a plate boundary. Hot Spots are thought to be the surface expression of giant plumes of heat, termed mantle plumes that ascend from deep within the mantle, possibly from the core-mantle boundary, some 2,900 km (1,800 miles) below the surface.



**Figure 2. Eurasia: Regions of High Seismicity & Historical Centre of Asian & European Migrations (4000 BCE to 1000 BCE).** Permission to use map format obtained by email: Sat, Jul 8, 2017 at 4:48 am, wangning<contact@yourfreetemplates.com>: "Your application in publication is permitted"



**Figure 3. The Boundaries of Major Tectonic Plates Showing Seismic "Hot Spots".** By courtesy of Encyclopedia Britannica, Inc., copyright 2017; used with permission. Plates <https://www.britannica.com/science/plate-tectonics>

Thus, colliding tectonic plates providing seismic “hot spots” cause underground rock friction and fracture are potent regions for emissions of environmental infrasound. Figure 2 shows regions up to 45°N are known to have exhibited a sustained high level of ethnic conflict including tribal migration from 4000 BC when Fergana Valley was the seat of Indo-European population migration and ethnic conflict over centuries. The relationship between exposure to infrasound and aversion to live in such mountainous localities becomes relevant here compelling local people to migrate in an epoch when world population was a small fraction of what it is today. But, so far no one has given any thought to a possible connection between infrasound emission and population migration

**Another Correlation: Latitude 34°N - Special Region of Well Recorded Conflict that threatens World Peace and Stability.**

It is seen that colliding tectonic plates (the Indian and Arabian Plates with the Eurasian plate) takes place in regions and seismic “hot spots” between 15°N and 45°N latitudes while sustained social disorder, and violent conflict regions are located at latitude 34°N (Table 1). Studies in other geologically similar regions of the world at the boundaries of clashing tectonic plates may reveal more such correlations. Of far greater relevance and importance is the observation that mountainous regions around Latitude 34°N ( $\pm 0.2^\circ$ ) shown in Table 1 that lie on the borderline of clashing tectonic plates (the Indian and Arabian tectonic with the Eurasian plate) are also those which have experienced earthquakes greater than  $M_w$  5.5 (Figure 3). It is hypothesized here that, *apart from other sociological, biological and geopolitical reasons*, environmental infrasound may be the root cause of such anomalous human behavior. Hence 34° N latitude in Central Asia may rightly be designated *Special Region for Experimental Research on Environmental Infrasound* and harmful effects on local populations. There are in all eight tectonic plates enveloping the surface of planet earth. Similar correlations are likely to exist in other regions where tectonic plates collide.

**Table 1. Distribution of Regions of High Seismicity (Earthquakes > Richter scale > 5.5, see Figure 1) Congruent with High Ethnic Conflict (Around Latitude 34°N)**

Sl. No	Location	Latitude (Degrees)	Variation from Average Latitude (Degrees)
1	Teheran, Iran	35.69	2.01
2	Kabul, Afghanistan	34.56	0.88
3	Tora Bora Caves Afghanistan	34.12	0.44
4	Srinagar, India	34.08	0.41
5	Lebanon	33.85	0.18
6	Islamabad, Pakistan	33.73	0.05
7	Damascus	33.51	-0.16
8	Baghdad	33.31	-0.36
9	Tel Avi, Israel	32.09	-1.59
10	Palestine	31.95	-1.72

## 7. Conclusions & Suggestions for Future Study

Scientific data referred in this paper have enabled to propose a correlation between tectonic plate movements

and location of seismic “hotspots” at the boundaries of tectonic plates and even within the body of the plates. Correlations have also been established for harmful effects of infrasound on individuals and small groups of people. Experimental studies are now necessary to correlate harmful effects of infrasound on larger populations on specific regions of “hot spots” and seismic activity at boundaries of tectonic plates.

### Experimental Studies

The science of Infrasonics is still very much at its infancy. Multidisciplinary studies over extended time periods to monitor infrasound emission from ground and atmospheric sources along with toxicology studies of infrasound can provide robust and more realistic insights on the influence of such geophysical and geo-acoustic phenomena to historically migratory and hostile behavior at population level. Limitations and difficulties in using these methodologies need to be documented and it can then be established definitively whether there is any relationship between environmental emissions of infrasound and anomalous human behavior not only in South Asia but also in other regions of high seismicity. This hypothesis requires immediate need for experimental verification at least in regions where terrain, soil, geological characteristics point to potential existence of environmental infrasound pollution; and also correspond to known region of sustained social conflict and violent human behavior.

### Alleviating the Harmful Effects of Environmental Infrasound: Active Infrasound Cancellation/Neutralization Technologies

Active noise control (ANC), also known as noise cancellation, or active noise reduction (ANR), is a method for reducing unwanted sound by the addition of a second sound specifically designed to cancel the first. The process is like smoothing the waves on the surface of a lake by creating anti-waves so that the peaks and the valleys of the two sets of waves cancel each other. This is not sound masking that adds a different kind of noise to cover-up the undesired noise. High frequency waves are difficult to reduce in three dimensions due to their relatively short audio wavelength in air. The most effective noise reduction in three-dimensional space involves low frequency sounds and Active Noise Cancellation is best suited for low frequencies [22]. Modern active noise control is generally achieved through the use of analog circuits or digital signal processing. Adaptive algorithms are designed to analyze the waveform of the background aural or non-aural noise, then based on the specific algorithm, generates a signal that will either phase shift or invert the polarity of the original signal. This inverted signal is then amplified and a transducer creates a sound wave directly proportional to the amplitude of the original waveform, *creating destructive interference*. This effectively reduces the volume of the perceivable noise. [1]

Once the precise location and causes of these “hot spot” emissions are precisely identified, design and development of such devices will be site specific. This work will consolidate the expansion of knowledge in the field of *electroacoustics* for the benefit of all mankind by adding a new dimension to interpretation and alleviation of global terrorism by alleviating the harmful effects of environmental infrasound pollution. The serene sounds of

silence would once again descend on mankind in these disturbed areas at the boundaries of colliding tectonic plates and seismic 'hot spots' in all continents and all affected nations. Better understanding of geo-acoustics of environmental infrasound pollution could well usher in a new era of world peace.

## References

- [1] Adewumi et al. "Reducing infrasound and low frequency noise from wind turbine blades and rotors using Active Noise Cancellation" Renewable Bioresources 2015. <http://www.hoajonline.com/journals/pdf/2052-6237-3-3.pdf>, Page 3, Column 2
- [2] J. Laštovičková, J. Bašea, F. Hrušková, J. Chuma, T. Šindelářová, J. Horálek, J. Zedník, V. Krasno "Simultaneous infrasonic, seismic, magnetic and ionospheric observations in an earthquake epicentre" Journal of Atmospheric and Solar-Terrestrial Physics, Volume 72, Issue 16, October 2010, Pages 1231-1240.
- [3] Xing Zhua, Qiang Xua, Jianbin Zhou, Minggao Tanga. "Experimental study of infrasonic signal generation during rock fracture under uniaxial compression".
- [4] M. Garce's, A. Harris, C. Hetzer, J. Johnson, and S. Rowland "Infrasonic tremor observed at Kilauea Volcano, Hawaii" Geophysical Research Letters, Vol. 30, No. 20, 2003.
- [5] Alfred J Bedard, NOAA Project MCAT, Experimental Technology Lab. 1998.
- [6] Inagaki, T., Li, Y. & Nishi, Y. Int. J. Environ. Sci. Technol. (2015) 12: 1933. Analysis of aerodynamic sound noise generated by a large-scaled wind turbine and its physiological evaluation 27 March 2014.
- [7] Abstract from Environmental Earth Sciences, 76: 228, "Observation of abnormal thermal and infrasound signals prior to the earthquakes: a study on Bonin Island earthquake M7.8 (May 30, 2015) March 2017.
- [8] Baliatsas C, van Kamp I, van Poll R, Yzermans. "Health effects from low-frequency noise and infrasound in the general population: Is it time to listen?" Sci Total Environ. 2016 Jul 1 557-558: 163-9.
- [9] Michael A. Persinger. "Infrasound, human health, and adaptation: an integrative overview of recondite hazards in a complex environment" Behavioural Neuroscience and Biomolecular Sciences Programs Laurentian University Sudbury Canada, Open Access Original Paper, 06 August 2016 (Cited Persinger, M.A. Nat Hazards (2014) 70: 501.
- [10] Landstrom, U., and M. Bystrom. "Infrasonic threshold levels of physiological effects" J. Low Freq. Noise Vib. 3(4): 167-173. EMBASE record 85174229, 1984.
- [11] Lindström, I.M. et al. "The effects of ultrasound on humans" Rep. (Umea University, Sweden) 33: 1-42. (Swedish) NIOSHTIC record 1997:71512, 1978.
- [12] Gerry Vassilatos "Lost Science" Limited permission granted to use this material in other presentations from "Deadly Sounds" Dr. Vladimir Gavreau ISBN 0-932813-75-5 © 1999
- [13] Reuters: The Associated Press updated 9/7/2003 11:41:25 AM ET [http://www.nbcnews.com/id/3077192/ns/technology\\_and\\_science-science/t/infrasound-linked-spooky-effects/#.WUzD\\_2eQxLM](http://www.nbcnews.com/id/3077192/ns/technology_and_science-science/t/infrasound-linked-spooky-effects/#.WUzD_2eQxLM)
- [14] Persinger, M.A. Nat Hazards (2014). "Infrasound, human health, and adaptation: an integrative overview of recondite hazards in a complex environment" Behavioural Neuroscience and Biomolecular Sciences Programs Laurentian University Sudbury Canada. 70: 501.
- [15] Abstract: Baliatsas C, van Kamp I, van Poll R, Yzermans J. "Health effects from low-frequency noise and infrasound in the general population: Is it time to listen? A systematic review of observational studies" Sci Total Environ. 2016 Jul 1; 557-558: 163-9.
- [16] Nath SK, Singh KK Thingbaijam and Raj A. " Earthquake hazard in Northeast India – A seismic microzonation approach with typical case studies from Sikkim Himalaya and Guwahati city "Department of Geology and Geophysics, Indian Institute of Technology Kharagpur 721 302, India J. Earth Syst. Sci. 117, S2, November 2008, pp. 809-831.
- [17] Calculation by Sri Thirumurthi , PhD Student , IIT (M) currently working on acoustics of combustion processes
- [18] Esther Pan, "India-Pakistan: Peace after the Earthquake?" Council on Foreign Relations, November 01, 2005.
- [19] Encyclopedia Britannica. "Plate tectonics" <https://www.britannica.com/science/plate-tectonics> (Figure 3 and Text with permission.
- [20] Figure 2 prepared with data and information from Charles DeMets, Richard G. Gordon and Donald F. Argus "Geologically current plate motions "Geophys. J. Int. (2010) 181, 1-80, Page 3.
- [21] Encyclopedia Britannica "Tectonic Plates" <https://www.britannica.com/science/plate-tectonics>
- [22] Infrasound "Wikipedia" <https://www.google.co.in/search?source=hp&q=active+noise+cancellation&oq=active+noise&gs>.