Infrasound and Low Frequency Noise: Medical Considerations

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### Historical Background

1973 – Paris - CNRS: Colloquium on Infrasound

-- Western World: dBA + what you can’t hear can’t hurt you”

-- Russian Legislation for Infrasound (2001):

<table>
<thead>
<tr>
<th>No.</th>
<th>Premise</th>
<th>Sound pressure levels, dB, in octaval bands of averaged geometric frequencies, Hz</th>
<th>General sound pressure level dB “Lin”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1.</td>
<td>Different jobs inside industrial premises and production areas:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Different physical intensity jobs</td>
<td>100</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>- Different intellectual emotional tension jobs</td>
<td>95</td>
<td>90</td>
</tr>
<tr>
<td>2.</td>
<td>Populated area</td>
<td>90</td>
<td>85</td>
</tr>
<tr>
<td>3.</td>
<td>Living and public premises</td>
<td>75</td>
<td>70</td>
</tr>
</tbody>
</table>
Swimming tests in normal rats and genetically deaf rat

-- 500–10 000 Hz:
No difference in swimming times in both groups

-- 6–50 Hz:
Swimming time was reduced in both deaf and non-deaf animals
Agents of Disease

-- Biological

-- Chemical

-- Physical

-- Psychosocial

World Health Organization:

Noise is inanimate mechanical forces

Physics (Acoustics):

Noise are airborne pressure waves.
Pressure = Force per unit area
Epidemiological Issues

ILFN is a Physical agent of disease.

Wind turbines ARE NOT agents of disease.

This misconception can lead to serious design flaws in epidemiological studies.

Comparing a population living near WTs with one who is not living near WTs is not scientifically valid, because the agent of disease is not the WT, but what it emanates.
Biological Tissues

Viscoelasticity vs. Hooke Elastic

-- Creep
Constant pressure leads to additional deformation

-- Stress relaxation
Constant pressure changes the strain response

-- Hysteresis
Pathway to strain is different from pathway after strain release

Biological tissues are viscoelastic. This feature imparts a non-linear response to ILFN exposure.
Biological Tissues

Tensegrity Architecture

Continuous Tension and Discontinuous Compression

Tensegrity structure. Any mechanical perturbation is distributed along the entire structure.

Old cell model, Balloon Model, Hooke elastic.

Tensegrity Cell Model. Explains mechanical signaling of cells, or, mechanotransduction
Tensegrity Structures

Cellular response to force along the vertical axis.

Cellular response to laminar flow.

- ‘Noise’ or airborne pressure waves impact viscoelastic tissues as ‘inanimate mechanical forces.’
- Cells respond via mechanotransduction pathways.
Epidemiological Issues

Confounding Factors:

-- Prior noise exposure (fetal, occupational, residential)

-- Noise exposure schedules

In Residential Studies

-- Not all members of the family develop the same symptoms at the same time

-- Additional exposure in the workplace will aggravate residential exposures

-- People who work at home will see a rapid onset of symptoms
A Mr. Smith has demanded compensation, from the Cork and Bandon Railway Company, for the injury which would be done to the milk of his cows, by reason of the noise, steam, and smoke of the locomotives in their transit!
Animal Studies

Scientists studying the effects of infrasound on animals:
- Russian
- Chinese
- Portuguese

Chinese & Russian studies are mostly:
- 2 or 3 hours/day
- Tonal presentation at 8 Hz and 16 Hz
- 90-130 dB
- 1, 7, 14, 21, 28, 35, 42 days

Portuguese studies are mostly:
- Continuous exposure or occupationally simulated
- Non-tonal presentation
- 70–100 dB
- 1–9 weeks
The Respiratory System

1969

“The lungs, as a system open to the external environment, are subjected to the greatest influence of changes in pressure in this medium. Depending on the magnitude of the pressure differential created by sound in the lungs during its transformation, and of the threshold of resistance of the lung tissue to pressure changes, the severity of the lung lesions gradually increases.”

1965
<table>
<thead>
<tr>
<th>Noise Source</th>
<th>Frequency Range (Hz)</th>
<th>dB Range</th>
<th>Frequency at max. dB (Hz)</th>
<th>Exposure Time</th>
<th>Subjective Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMRL3 High Intensity Noise Facility</td>
<td>8-1000</td>
<td>95-122</td>
<td>100</td>
<td>2 min</td>
<td>mild chest wall (5) and body hair vibration (5)</td>
</tr>
<tr>
<td>J57 Turbojet Aircraft Engine</td>
<td>6-1000</td>
<td>112-135</td>
<td>100</td>
<td>1 min</td>
<td>mild chest wall vibration (5); &quot;awareness&quot; of respiratory action (1)</td>
</tr>
<tr>
<td>NASA-LRC4 Thermal Structures Tunnel</td>
<td>3 - 10000</td>
<td>117-138</td>
<td>40</td>
<td>1 min</td>
<td>mild chest wall (2) &amp; nasal cavity (2) vibration; perceptible throat fullness (1)</td>
</tr>
<tr>
<td>NASA-LRC Thermal Structures Tunnel</td>
<td>3-10000</td>
<td>102-135</td>
<td>80</td>
<td>25 sec</td>
<td>mild-moderate chest wall vibrations (5); interference with normal respiratory rhythm (3); throat pressure (2)</td>
</tr>
<tr>
<td>NASA-LRC Low Frequency Noise Facility</td>
<td>10-60</td>
<td>118-140</td>
<td>30</td>
<td>2 min minimum</td>
<td>moderate chest wall vibration (5); hypopharyngeal fullness (gagging) (5); perceptible visual field vibration (5)</td>
</tr>
<tr>
<td>USAF-RTD5 Sonic Fatigue Facility</td>
<td>100 (discrete signal)</td>
<td>153</td>
<td>n/a</td>
<td>2 min minimum</td>
<td>coughing, severe substernal pressure, choking respiration, salivation, pain on swallowing, hypopharyngeal discomfort (5)</td>
</tr>
</tbody>
</table>
### Boiler plant workers

Two years after the mandatory use of hearing protectors among workers

<table>
<thead>
<tr>
<th>Organ System</th>
<th>Symptomatic Complaint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allergenic and Dermatological</td>
<td>Skin Itching, Skin Burning</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Coughing, Congestion in Head and Chest, Shortness of Breath, Hoarseness</td>
</tr>
<tr>
<td>Neurological</td>
<td>Headaches, Dizziness, Numbness</td>
</tr>
<tr>
<td>Digestive</td>
<td>Stomach Cramps, Nausea, Diarrhea, Heartburn</td>
</tr>
<tr>
<td>Urological</td>
<td>Irregular Urination, Pain in Bladder area, Blood in Urine</td>
</tr>
<tr>
<td>Muscular and Skeletal</td>
<td>Backaches and Neck Aches, Soreness in Muscles, Cramps</td>
</tr>
</tbody>
</table>

1976
Clinical Stages of Vibroacoustic Disease for Occupational Exposures

**MILD**
1-4 years of ILFN exposure
Slight mood swings, indigestion & heartburn, repeated mouth & throat infections, bronchitis.

**MODERATE**
4-10 years of ILFN exposure
Chest pain, back pain, fatigue, fungal & viral skin infections, allergies, blood in urine, inflammation of stomach lining.

**SEVERE**
> 10 years of ILFN exposure
Psychiatric disturbances, headaches, hemorrhages of nasal & digestive mucosa, duodenal ulcers, spastic colitis, varicose veins & hemorrhoids, decreased vision, severe joint pain, severe muscular pain, neurological disturbances.

Alveolar Wall Thickening

The scale of these two micrographs is the same.
Rat Trachea - 2213 hrs
Mitochondria

Swollen or giant mitochondria in ILFN-exposed:

-- Ocular structures: blood-retinal barrier and retinal layers (China 2002, 2008)

-- Oocyte (China, 2003) and testis (China 2003)

-- Hepatocytes with crest deformation; increasing severity with increasing exposure time (Russia 1991, 1992)

-- Cardiomyocytes (Russia 1983, China 2007, Portugal 2013)

-- Pneumocytes Type I and Type II (Russia 1987)

-- Cerebral cortex neurocytes (China 1997)

-- Vestibular and middle cochlear cells (Russia 1990)
**Cardiovascular System**

WHO 2011 – Burden of disease caused by noise:

- Ischemic heart disease
- Cognitive impairment
- Sleep disturbances

TRP channels (transient receptor potential) that are important for ILFN-induced pathology because they are mechanosensitive and thermosensitive:

TRPV1, TRPV2, TRPV4, and TRPA1
Cardiovascular Thickening

Prior Autopsy and animal studies:

Thickening of cardiovascular structures:
-- Blood Vessel Walls

Thickened artery wall in 'noise'-exposed rat.

Thickened artery wall in patient's pericardial loose-tissue layer.
Prior Autopsy and animal studies:

Thickening of cardiovascular structures:
-- Pericardium

**Normal pericardium**
- <0.5 mm thickness
- **Three layers** of tissue:
  - Serous
  - Fibrous
  - Epipericardium
The scale of these two micrographs is the same.
Teratogenesis

VAD Team Laboratory
Rat exposed in utero

Wind Turbine Home Horses

Chicken exposed to Infrasound and Low Frequency noise generated by coal mining operations before hatching
Thank you for your attention!

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Succulent plant exposed to Northern winds on Madeira Island – North Atlantic Ocean.

Bronchial brush cell of Rat exposed to infrasound and low frequency noise.