Precautionary Strategies for Reducing Worker Exposures to Extremely Low Frequency (ELF) Magnetic Fields, a Possible Carcinogen

Joseph D. Bowman, PhD
National Institute for Occupational Safety and Health
Cincinnati, OH

The findings and conclusions in this presentation are those of the author and do not necessarily represent the views of the National Institute for Occupational Safety and Health.
Outline

• Overview of NIOSH and other federal agencies involved with EMF
• What is EMF?
• Precautionary strategies to reduce workers’ possible cancer risks from extremely low frequency (ELF) magnetic fields
• Q&A
NIOSH’s role in occupational safety and health

- Sets standards
- Enforces standards
- Provides information

- Conducts research
- Recommends standards
- Advises workers and employers
- Evaluates health hazards upon request
Federal agencies doing EMF research and regulation

- National Cancer Institute (NCI)
- National Toxicology Program (NTP)
- CDC
- FDA
- EPA
- FCC
- OSHA
- NIOSH
- National Center for Environmental Health (NCEH)
- RF interagency working group (RFIAWG)
What are EMF?

- EMF are force fields emitted by electricity

- Voltage ➔ Electric fields
  - Like plugging a person into an electric socket

- Current ➔ Magnetic fields
  - Like having an electric generator inside
Sources of high ELF electric fields

Substations

Transmission lines
Sources of high ELF magnetic fields

- Transformer
- Electrochemical cells
- Bare-hands work on live transmission lines
- Metal welding
- Steel furnace
Magnetic Field Properties and Units

- **Shielding:** unaffected by matter, except thick steel

- **Units:**
  - **Static & ELF:** Magnetic flux density in microtesla [\(\mu T\)]
    - Milligauss (mG) often used in North America
    - Microtesla used in most other scientific papers and reports
    - 1 \(\mu T = 10\) mG
  - **RF:** Magnetic field strength in amperes per meter [A/m]
    - 1 \(\mu T = 1.26\) A/m in air and biologic tissues

![60 Hz magnetic field from AC circuit](image1)

![Radio frequency radiation](image2)
Precautionary strategies for managing occupational ELF magnetic fields

Outline

• Meaning of *Possibly Carcinogen to Humans* rating by IARC and WHO
• Quantitative risk assessment for ELF-MF and cancer
• Dutch study of precautionary measures*
• Messages to persuade industrial hygienists, managers and workers to adopt precautionary measures

*JD Bowman and Y Christopher-de Vries, Evaluation of Precautionary Controls for Occupational ELF Magnetic Fields in Dutch Workplaces, AIHce (2014); BioEM (2015).
Problem

• ELF magnetic fields are Possibly Carcinogenic to Humans
  • Based on epidemiology:
    • Childhood leukemia with home exposures
    • Brain cancer and leukemia from occupational exposures
  • Animal studies inconclusive in 2007
  • No proven mechanism in 2007
  • Interpretation: Credible risks have been observed, but they may be due to errors.

• WHO’s *Environmental Health Criteria* on ELF-MF:
  “low-cost precautionary procedures to reduce exposures [are] reasonable and warranted ...”

• But precautionary methods for reducing workplace exposures are lacking
NIOSH’s Proposed Resolution

   - Risk of dying prematurely decreases by $0.32\% \pm 0.29\%$ per 1 $\mu$T reduction in time-weighted average (TWA) magnetic field magnitude

**Deaths attributable to occupational ELF-MF compared to other causes of death**

- Evidence-based precautions: Low cost measures to reduce TWA
NIOSH’s Proposed Resolution

2. Dutch study to develop and test precautionary measures
   • Collaboration with EMF Professor Hans Kromhout, U. Utrecht

3. Develop and test messages to persuade industrial hygienists, managers and workers to adopt precautionary measures
   • Started with Dutch study and has been continuing in the US

4. Publish NIOSH bulletin to advise industrial hygienists on managing cancer risks
   • Concept approved by the NIOSH Lead Team in 2012
## Participating Dutch companies and their strong ELF magnetic field sources

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Magnetic Field Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railroad car refitting plant</td>
<td>Magnetic fault testers, induction heaters, <em>induction furnace</em>, arc welding</td>
</tr>
<tr>
<td>Auto body plant</td>
<td><em>Spot resistance welding</em>, arc welding, electric power center</td>
</tr>
<tr>
<td>Plastics company</td>
<td><em>Chlorine electrolysis cells</em>, rectifier room, electric power center</td>
</tr>
<tr>
<td>Paper mill</td>
<td>Generator, <em>transformers</em>, large motors, arc welding, electric fork lift</td>
</tr>
</tbody>
</table>
Tools for Designing Controls

• Personal monitoring with task log
  • High exposure tasks
  • Duration of exposure

• Spot measurements
  • Identify sources
  • Fall off with distance

• Basic IH principles:
  ↑ distance, ↓ time, ↓ reps

• Modeling
Precautionary measures
*Railroad car refitting plant*

<table>
<thead>
<tr>
<th>Source</th>
<th>Exposure reduction measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Induction furnace</td>
<td>Install remote control</td>
</tr>
<tr>
<td>Handheld fault tester</td>
<td>Purchase lower emission model</td>
</tr>
<tr>
<td>Metal induction heater</td>
<td>Increase distance when operating</td>
</tr>
<tr>
<td>Arc welder</td>
<td>Do not run cable over the shoulder</td>
</tr>
</tbody>
</table>

Spot measurements determine control’s position

Cable crossing the body
Worker Training Presentations for Dutch study

- Outline
  - What are EMF?
  - Health risks
    - Definite risks $\Rightarrow$ standards
    - Possible risks $\Rightarrow$ precautionary measures
  - How worker can reduce TWA exposures

Risk gauge compares worker cancer risks from TWA measurements to other causes of death.
Effects on exposures – *Paper mill*

However, no company fully implemented the worker training.
Lessons Learned

Barriers to Acceptance of Precautionary Measures

• Controversy over science

• Not a regulation

• Other hazards are higher priorities

• Reluctance to raise cancer issue with workers

• Telling workers about cancer and EMF may create fear


Lesson: Messages need improvement.
Next Steps

• Two *Current Intelligence Bulletins* planned:
  • Managing electromagnetic interference with implants
  • Cancer precautions + Recommended Exposure Limits for neurological effects

• Website with additional information

• NIOSH review and approval process will require several years
Other precautionary measures from the Dutch study
# Precautionary measures

## Auto body plant

<table>
<thead>
<tr>
<th>Source</th>
<th>Exposure reduction measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc welding</td>
<td>Do not run cable over the shoulder</td>
</tr>
<tr>
<td><strong>Manual spot welding</strong></td>
<td><strong>Re-design process</strong></td>
</tr>
<tr>
<td>Robotic spot welding</td>
<td>Electric-work-only zones</td>
</tr>
<tr>
<td>Power center</td>
<td>Electric-work-only zones</td>
</tr>
<tr>
<td>Other jobs</td>
<td>Training on EMF hazards and exposure reduction</td>
</tr>
</tbody>
</table>

**Control:** Place metal parts into jig and step back to weld
Precautionary measures
*Plastics plant*

<table>
<thead>
<tr>
<th>Source</th>
<th>Exposure reduction measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine cell hall</td>
<td><strong>Electric-work-only zones</strong></td>
</tr>
<tr>
<td></td>
<td>Install video cameras to decrease inspections</td>
</tr>
<tr>
<td></td>
<td>Turn surrounding cells off during repairs</td>
</tr>
<tr>
<td>Power center</td>
<td><strong>Electric-work-only zones</strong></td>
</tr>
<tr>
<td>Rectifier room</td>
<td><strong>Electric-work-only zones</strong></td>
</tr>
<tr>
<td>Other jobs</td>
<td>Training on EMF hazards and exposure reduction</td>
</tr>
</tbody>
</table>

![Graph showing Rectified Magnetic Field over Time (msec)](image)

Electrolysis cell hall
Electric-work-only Zones
in the electrolysis cell hall

Work practices for electric-work-only zones
- First prepare all tools
- Step out of zone for other tasks
- Do not take any safety risks.

Decrease time in high field areas
Precautionary measures

*Paper mill*

<table>
<thead>
<tr>
<th>Source</th>
<th>Exposure reduction measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power plant</td>
<td>Electric-work-only zones</td>
</tr>
<tr>
<td><strong>Transformers by walkway</strong></td>
<td><strong>No-go zone</strong></td>
</tr>
<tr>
<td>Arc welding</td>
<td>Do not run cable over the shoulder</td>
</tr>
<tr>
<td>Maintenance mechanics</td>
<td>Identify sources to avoid, e.g. large motors</td>
</tr>
<tr>
<td>Other jobs</td>
<td>Training on EMF hazards and exposure reduction</td>
</tr>
</tbody>
</table>

![Diagram showing Power plant and Transformers]

19.0 µT

Do not go into *no-go zone* except for work.