Electromagnetic Fields and Human Health

Static and Extremely Low Frequency (ELF) Fields

WORLD HEALTH ORGANIZATION

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I. Introduction

- This presentation discusses health effects of static and extremely low frequency (ELF) electromagnetic fields:
  - static fields are time-independent fields of constant strength, whereas
  - extremely low frequency (ELF) fields are oscillating fields defined as having frequencies below 300 Hz
- ELF fields are very important from a public health standpoint because of the widespread use of electrical power at 50 or 60 Hz in most countries

Introduction (contd.)

- Furthermore, there is still much concern in the general public about the consequences of exposure to these fields, for example near power lines and in industries
- In this presentation, we first explain some important theoretical concepts related to the study of static and ELF fields
- By summarizing the results published in the scientific literature, we then give an overview of our current state of knowledge regarding their possible effects on human health

II. Sources of Exposure

- To put things in perspective, we first list some common static and ELF fields found in our environment
- Tables in the following slides present the typical field strengths of :
  - Sources of static fields
  - Sources of ELF fields
- We also introduce the concept of transients, which are high-intensity “surges” in the fields produced by certain devices

Sources of exposure to static fields

Typical electric fields

Atmosphere (naturally-occurring)	12-150 V/m
Near TV set, video display unit	20 kV/m
Under 500 kV transmission line	30 kV/m

Typical magnetic fields

Geomagnetic field (naturally-occuring)	0.03-0.07 mT
Industrial DC equipment	50 mT
Magnetic levitation train	50 mT
Small bar magnets (locally)	1-10 mT
Magnetic resonance imaging (MRI)	2.5 T

Sources of exposure to ELF fields

Typical electric fields

Naturally-occurring (50/60 Hz)	0.1 mV/m
Underneath AC transmission lines	12 kV/m
Around electricity generating stations	16 kV/m
Around appliances	0.5 kV/m

Typical magnetic fields

Naturally-occurring (50/60 Hz)	0.01 nT
Underneath AC transmission lines	10-30 µT
Around electricity generating stations	40-120 µT
Around appliances	50-150 µT
Industrial processes (e.g., welding)	130 mT
Average 50/60 Hz fields in residences	0.1-0.3 µT

Transients

- When current or appliances are turned on and off (switching), short and intense pulses called transients are produced:
  - Magnetic field transients can vary between 0.001 to 10 µT and can have component frequencies from below 60 Hz up to 500 MHz
- Biological effects of transients are not well understood yet; until now, few epidemiological studies have taken them into account
- Their relative importance when evaluating a person's exposure remains unclear

III. Dosimetry

- When performing studies on humans, we need ways to quantify a person's exposure
- Dosimetry aims to identify the aspects of fields that are directly related to biological effects in order to determine an EMF "dose"
- This allows us to verify, for example, if increasing the dose causes greater effects (known as a dose-response relationship)
- For high exposure levels, the biological effects and the concept of dose are well understood

Dosimetry (contd.)

- However, for lower environmental levels, the reported effects are not well enough understood to establish precisely how doses should be calculated...
- For example, how should transients be included?
- These questions are important in research for:
  - designing exposure assessment protocols for epidemiological studies
  - translating exposure of humans to equivalent animal or cellular exposures in laboratory experiments

IV. Interaction Mechanisms

- In this section, we explain the physical phenomena that occur when a living system is exposed to each type of field:
  - Effects of static electric fields
  - Effects of static magnetic fields
  - Effects of ELF electric fields
  - Effects of ELF magnetic fields
- We also discuss theoretical principles that must be considered when trying to explain how electromagnetic fields might cause health effects

Static electric fields

- The interior of conducting objects, such as the human body, is shielded from static electric fields
- However, they induce an electric charge on the surface of exposed humans; this can be perceived by movement of body hair if the fields are strong
- In addition, on touching a metal object, a “charged” person can experience an electric shock or spark
- Besides these effects, no other direct action of static electric fields on living systems is known

Static magnetic fields

- Contrarily to electric fields, static magnetic fields can penetrate biological tissues freely
- They can interact directly with moving charges (ions, proteins, etc.) and magnetic materials found in tissues through several physical mechanisms
- However, at environmental field levels, the only significant mechanism is the induction of static *electric* fields and currents in the tissues
- Thus, although external electric fields cannot penetrate it, external magnetic fields can cause electric fields to be generated within the body

ELF electric fields

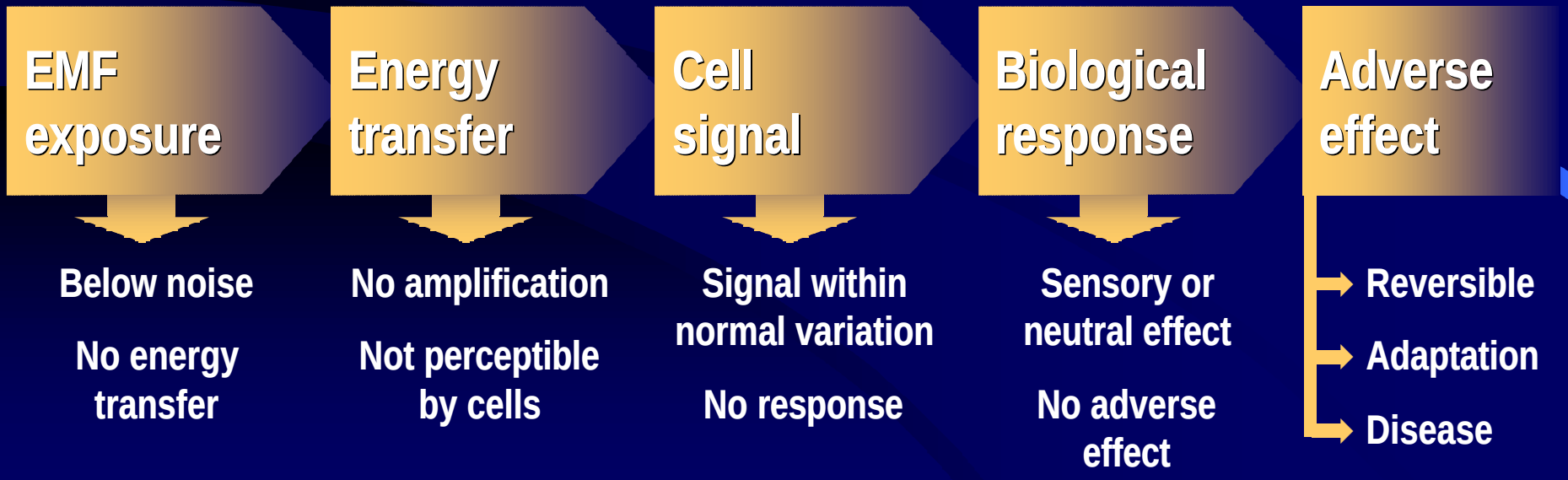
- Just as a static electric field causes a charge to appear on the body's surface, an oscillating ELF field will induce a charge that varies continuously and regularly in time
- In turn, this constant flow of surface charge will give rise to oscillating *internal* electric fields and currents
- However, these effects depend on frequency and remain very small for the ELF range
- Typically, induced electric fields are more than one million times weaker than the external field

ELF magnetic fields

- Oscillating magnetic fields can also induce electric fields and currents, but mostly in the superficial tissues
- These effects are also dependant on frequency and are small for ELF
- In contrast, the transient magnetic fields that are produced during switching can induce strong electric fields and currents, but only for very short time periods

Theoretical principles

- For electric or magnetic fields to cause health effects, they must first *interact* with biological molecules or structures and *induce a change by transferring energy*
- In turn, this must generate a *signal* that can be sensed and amplified by cells to produce a subsequent *response* of the organism… that might be harmful or not



Physical models

- Many scientific models have been proposed to explain the fundamental way in which ELF fields might interact with cells and tissues:
  - Direct transfer of energy
  - Forces on charged molecules, such as proteins
  - Increase of lifetime of free radicals
  - etc.

- However...

Signals versus noise

- The environment of living cells is electrically "noisy" because there are random movements of ions and charged molecules
- If a "signal" induced by an ELF field is to be perceived by a cell, it must be stronger than the the average noise level
- This principle can serve to evaluate the plausibility of proposed scientific models, and...
- At environmental field levels, most models appear to be physically impossible!

V. Laboratory Studies

- Having discussed theoretical aspects, we now turn to experimental results
- We begin by reviewing the laboratory studies that have investigated the effects of:
  - Static electric fields
  - Static magnetic fields
  - ELF electric and magnetic fields

Static electric fields

- Many experiments with static electric fields have been conducted
- Examples of subjects studied include:
  - Circadian rhythms in humans and rodents
  - Hematology, reproduction, prenatal and postnatal survival in animals
- All have failed to demonstrate any adverse health effects of static electric fields (except the danger of experiencing shocks explained previously)
- No further research is considered necessary

Static magnetic fields

- A large number of static magnetic field studies have been performed on cells and cellular components, genetic material, embryogenesis, the central nervous system, behavior, etc.
- When taken as a whole, they do not suggest any detrimental effects on major development, behavioral or physiological parameters for short-term exposures (up to about 2 T)
- However, long-term toxicology experiments on animals still need to be conducted to assess effects of chronic exposure

Static magnetic fields (contd.)

- In occupationally-exposed workers, certain studies have found an increased risk of mortality and cancer
- However, other possible carcinogens and environmental contaminants were commonly found in industries and their effects were not properly investigated
- It is thus impossible to attribute the increased risk to magnetic field exposure without further assessing the impact of these other factors

ELF electric and magnetic fields

- Many effects of ELF fields are observed when levels of induced electric fields and currents exceed the body's natural electrical signals
- Despite inconsistent or irreproducible results, other studies have reported a variety of *in vitro* effects at lower levels:
  - changes in cell proliferation, metabolism, gene expression, protein synthesis, enzyme activities, etc.
- These observations are not necessarily indicative of adverse health effects in humans; a better knowledge of mechanisms involved is required

ELF electric and magnetic fields (contd.)

- There is also some conflicting evidence about whether ELF can alter DNA and thus contribute to carcinogenesis...
- Overall, findings suggests that ELF does not cause cancer, but might alter it’s progression
- Another effect of ELF magnetic fields observed in rodents is a decrease in melatonin levels
- However, this was not found to be related to any adverse health effects, and a similar decrease has not been demonstrated in humans

VI. Epidemiological Studies

- Most epidemiological studies have focused on magnetic fields, though some have also studied electric fields
- Results pertaining to the most studied diseases are reviewed in the following slides:
  - Cancer
  - Reproductive outcomes
  - Neurological and psychiatric diseases

Cancer

- TO DO
- FOR THIS SLIDE, use conclusions from ELF fact sheet for consistency

Reproductive outcomes

- Studies of pregnancy outcomes in women working with visual display units (VDUs) have provided no consistent evidence for adverse effects on reproduction
- In addition, meta-analyses of combined studies found no excess risk of spontaneous abortion or malformations
- However, studies evaluating effects of residential exposure to ELF have given conflicting results, some suggesting a slight increase of early pregnancy loss

Neurological and psychiatric diseases

- Certain studies have reported an apparent increase of diseases such as Alzheimer's disease in specific worker groups that are submitted to high exposure levels
- These findings need further examination and follow-up
- Though suggested by some reports, associations with suicide and depression have not been well established; more research is also necessary

VII. Human Studies

- Human laboratory studies have been conducted on the following systems:
  - Cardiovascular
  - Brain and behaviour
  - Hormonal and immune systems
- The main results are summarized in the next slides

Cardiovascular

- It has been reported that under precise circumstances, ELF fields can influence the cardiovascular system, for example by slightly decreasing or increasing the heart rate (by about 3-5 beats/minute)
- Nevertheless, no obvious acute or long-term cardiovascular-related hazards have been demonstrated at levels below current exposure standards

Brain and behavior

- Because nervous tissue is sensitive to electrical signals, the brain is a likely site of interaction with ELF fields
- Experiments suggest that effects can occur, but only when certain threshold levels of induced currents are reached:
  - modification of brain waves
  - changes in response time for complex reasoning tasks
  - changes in time perception

Hormonal and immune systems

- It has been suggested that magnetic fields might reduce levels of the hormone melatonin and that this might explain their relationship with cancer, if one exists
- Some studies have found decreased levels of melatonin in occupationally-exposed workers
- In contrast, well-controlled human laboratory studies report mostly negative results
- Further work must be done regarding these possible effects

VIII. Conclusion

- Despite the large number of studies already reported, further research is still necessary in order to make a complete assessment of health effects of exposure to static and ELF fields
- Many inconsistencies must be resolved, reported effects must be replicated and major concerns (e.g. cancer) must be properly addressed
- Advances in our knowledge will allow better evaluation of possible risks and ensure that exposure guidelines provide adequate protection for all, both in the community and workplace