

Electromagnetic Fields and Human Health

Static and Extremely Low Frequency
(ELF) Fields



WORLD HEALTH ORGANIZATION

Contents of the presentation

I. Introduction

II. Sources of Exposure

III. Dosimetry

IV. Interaction Mechanisms

V. Laboratory Studies

VI. Epidemiological Studies

VII. Human Studies

VIII. Conclusion

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-occurring)	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 μ T
Around electricity generating stations	40-120 μ T
Around appliances	50-150 μ T
Industrial processes (e.g., welding)	130 mT
Average 50/60 Hz fields in residences	0.1-0.3 μ T

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

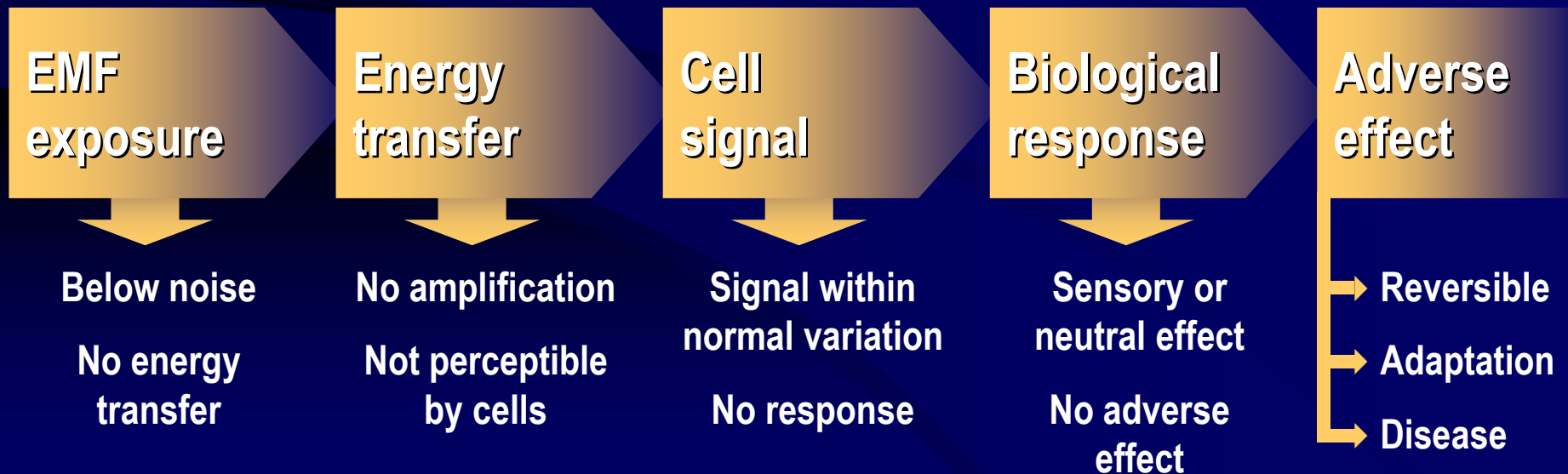
- ▶ Just as a static electric field causes a charge to appear on the body's surface, an oscillating ELF field will induce a charge that varies continuously and regularly in time
- ▶ In turn, this constant flow of surface charge will give rise to oscillating *internal* electric fields and currents
- ▶ 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

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