Static electric and magnetic fields and health

Prepared by Belgian BioElectroMagnetics Group (BBEMG)

In the 19th century, at the dawn of the electric era, high voltage AC transmission system (50/60 Hz) was chosen at the expense of DC transmission (0 Hz). Nevertheless, high voltage DC is used to transmit electrical energy over long distances, including under the sea, and to interconnect different frequency networks (eg in Japan, for interconnection between 50 Hz network in the north and 60 Hz network in the south).

And the situation continues to evolve. Indeed, the need to interconnect countries to ensure trade in electricity (eg interconnection Nemo Link®[1] in the North Sea and interconnection ALEGrO[2]) and the relocation of electricity production plants (eg wind farm in the North Sea) involve the development of electrical connections on long distances, which are more effective in DC. Moreover, in Belgium for example, trains, excluding high speed train, also operate in DC.

Note: Detailed information on the challenges of transport in both AC and DC power are available at Electricity network.

Local residents are concerned: are DC electric and magnetic fields (EMF) harmful for our health?

Some key figures…

A static field is a field that does not change its sense, unlike fields of electricity network (50/60 Hz) and radiofrequency fields (GHz). This field is either electric (EF) or magnetic (MF).

The intensity of the static EF depends on the voltage, while the intensity of the static MF depends on the force of a magnet or the intensity of the flowing current.

1 Static electric field (or electrostatic)

There is a natural static electrical field at the surface of the earth. It is created by the potential difference between the upper atmosphere (the ionosphere, positively charged) and earth (negatively charged). In calm weather, this electric field is of the order of **100 to 150 V/m**, but during storms it can reach **15 to 20 kV/m** (15 000 to 20 000 V / m).

Static EF is also the basis of electrostatic discharges that we sometimes feel when getting out of a car by cold and dry weather conditions, for example. These discharges are due to the generation of an electric field between the car and the body, a hand for example. If the field is sufficiently high, i.e. if it exceeds the air-breakdown field (approximately 300 kV/m, depending on the humidity, pollution...), air becomes electrically conductive and the charges accumulated by the car will instantaneously flow to the ground. Static EF at the hand reaches values above the air-breakdown field.

[1] http://www.nemo-link.com/fr/
[2] http://www.elia.be/fr/projets/projets-reseau/alegro/alegro-content

Static EF that can be measured under DC transmission lines or railway lines are respectively close to 20 to 30 kV/m and 600 V/m. These are maximum values measured in the absence of any obstacle because EF is easily reduced.

In a DC train, a static EF close to 300 V/m can be measured (Source: ICNIRP).

2 Static magnetic field

Static MF are typically those measured between the two poles of a magnet. Among the magnets usually used, intensities are around 10 mT (10,000 microT).

Our earth is a big magnet that, thanks to the force lines of the static MF between its two poles, protects us from radiations coming from space. The geomagnetic field is about **45 µT** in Belgium. Among medical devices, MRI uses a super magnet whose intensity can vary between **1.5 and 10 T** (1.5 million and 10 million µT).

Nearby DC system, static MF of tens of µT can be measured under the electricity transmission lines and about 200 µT under a railway line. When we move 5 m away, lower values are measured: 10 µT for the transmission lines and about 100 µT for train lines.

In a train, static MF is around 40 µT. Maximum values of 120 µT have been measured in DC powered locomotives (3 kV DC as in Belgium, measurements carried out in Russian and Italian trains).

How static electric and magnetic fields can interact with our body?

1 Static electric field (or electrostatic)

The particularity of static EF is to exert forces on charged particles (positive or negative electric charges).

Static EF does not enter our body; it induces movements of electric charges at the body surface.

These movements will be perceived for example at the level of hair. They are also involved in electrostatic discharges. At high intensity, we can feel static EF in hair.

(Source: Maison de la Science, Université de Liège)

2 Static magnetic field

Static MF exerts forces on metals (cf. magnet) and on moving electric charges.

By interacting with metals, high magnetic fields can interfere with implanted medical devices, such as pacemakers, comprising a metallic material. Furthermore, hemoglobin, a protein present in our red blood cells useful in the transport of oxygen in the body, contains iron, as well as ferritin, another protein that stores iron in the body (ferritin screening is used to follow iron deficiency or overdose). These proteins may be sensitive to static magnetic fields, but their very small size makes unlikely the

possibility of an effect. Similarly, magnetite (iron oxide Fe3O4) has been assayed in some animals. It is involved in the migratory behaviour of several of them. Its presence in humans is not confirmed to date (see insert below).

Magnetic sensitivity - Our body has always been submitted to Earth's geomagnetic field. Are we sensitive?

Ability to detect geomagnetic field is one of the elements that explain the migration of certain animals (birds, fishes ...). This magneto-reception is due on one hand to the presence of magnetite crystals and on the other hand to proteins called cryptochrome, present in the retina for example.

Magnetite crystals have been detected in many animals, migrants or residents, but their presence is not confirmed in humans. They react like a compass needle and can follow the direction of the geomagnetic field.

Many experiments have shown that magnetite was not the only one involved in the migratory behaviour. In fact, the retina contains a protein (cryptochrome) susceptible to light and which is in some animals a magneto receiver. This protein is also present in humans. It is involved in the regulation of biorhythms and would not or no longer have a function related to geomagnetic field.

Some animals are sensitive to geomagnetic field without being migratory. Magnetic sense might therefore also contribute more generally to spatial recognition (J Vanderstraeten, 2013).

Let us look at the second characteristic of static MF, ie their action on moving electric charges. Two situations have been well studied:

- **When we are motionless in a high static MF**, electrical charges are still moving in our bodies: including charges in the blood flow. Interactions are extremely weak, but modelling showed a change in the moving velocity of the blood in large vessels subjected to a perpendicular static field.
- **When moving in a high static MF**, the opposite occurs: static MF may act on static fluids in our body, for example on the liquid in the inner ear involved in balance. This interaction can cause feelings of dizziness or nausea (WHO, 2006).

These effects only occur in the presence of particularly high static MF, above a few teslas, and they are temporary, ie they disappear with increasing distance from the source.

What are the results of studies on health effets of static fields?

Relatively few studies have been conducted on exposure to static fields. They generally conclude to the absence of health effects.

1 Static electric field (or electrostatic)

The only effects retained are perceptions of hair movements and electrostatic discharges in the presence of high fields. These effects are associated with acute exposure. To date, no study has been conducted on the long-term effects of static EF.

2 Static magnetic field

Researchers studied many potential health effects, such as effects on fertility, growth and development, on cancer, on cardiovascular and systems, on cognitive function ... (Health Protection Agency 2008). They worked on cells and animals and also conducted experimental or epidemiological studies in humans.

Apart from temporary effects such as dizziness or nausea, transient decreases in performance... reported by people moving in high static MF, studies do not put in advance any effects on health. These temporary effects are pursued because they can cause anxiety in people who are the victims.

There is no evidence of long term effects such as cancer. Further studies are needed to determine the effects of high static MF and long-term exposure.

Recommendations

1 Static electric field (or electrostatic)

Current guidelines do not recommend limiting static EF levels.

2 Static magnetic field

The following limits are recommended by ICNIRP (2009):

- ➔ For workers: 2T for the head and the trunk, and 8T elsewhere
- ➔ For the public: 400 mT for all parts of the body

For implanted electronic medical devices, the limit is set to 0.5 mT.

The 2013/35/EU European Directive for the protection of workers advocates the same values as ICNIRP. Moreover, in occupational environments, exposure up to 8 T is tolerated for the entire body, if the environment is controlled and work practices are adapted to reduce the speed of execution and movements in such fields.

References

Contessa GM, Falsaperla R, Brugaletta V, Rossi P. Exposure to magnetic fields of railway engine drivers: a case study in Italy. Radiat Prot Dosimetry. 2010 Dec;142(2-4):160-7. doi: 10.1093/rpd/ncq270. Epub 2010 Nov 11.

Health Protection Agency (2008). Static magnetic fields, Report of the independant Advisory Group on Non-ionising Radiation. Documents of the Health Protection Agency – Radiation, Chemical and Environmental Hazards.
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/335120/RCE-6_for_Web_16-05-08.pdf

Directive 2013/35/UE du parlement européen et du conseil du 26 juin 2013
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:179:0001:0021:FR:PDF

International Commission On Non-Ionizing Radiation Protection. ICNIRP guidelines on limits of exposure to static magnetic fields. Health Physics 96(4):504-514; 2009.
http://www.icnirp.org/cms/upload/publications/ICNIRPstatgdl.pdf

Leitgeb N. Limiting electric fields of HVDC overhead power lines. Radiat Environ Biophys. 2014 May;53(2):461-8. doi: 10.1007/s00411-014-0520-2. Epub 2014 Feb 27.

Perrin A, Souques M (2010). Champs électromagnétiques, environnement et santé. Paris, France : Springer Paris.
http://books.google.be/books/about/Champs_%C3%A9lectromagn%C3%A9tiques_environnemen.html?id=VuhxH24C2GEC&redir_esc=y

Ptitsyna NG1, Kopytenko YA, Villoresi G, Pfluger DH, Ismaguilov V, Iucci N, Kopytenko EA, Zaitzev DB, Voronov PM, Tyasto MI. Waveform magnetic field survey in Russian DC and Swiss AC powered trains: a basis for biologically relevant exposure assessment. Bioelectromagnetics. 2003 Dec;24(8):546-56.

Vanderstraeten J. (2013). Analyse de l'hypothèse de la perturbation des biorythmes par les champs magnétiques d'extrêmement basse fréquence Mécanismes possibles, impact en santé publique, protocoles de mise à l'épreuve. Thèse présentée en vue de l'obtention du titre de Docteur en Sciences de la Santé Publique
http://theses.ulb.ac.be/ETD-db/collection/submitted/ULBetd-05152013-002823/restricted/Vanderstraeten_THESE.pdf

Greenfacts, Champs statiques : http://www.greenfacts.org/fr/champs-statiques/index.htm#1

ICNIRP, Static electric fields 0 Hz:
http://www.icnirp.org/en/frequencies/static-electric-fields-0-hz/index.html

ICNIRP, Static magnetic fields 0 Hz
http://www.icnirp.org/en/frequencies/static-magnetic-fields-0-hz/index.html

Organisation Mondiale de la Santé, Champs électromagnétiques et santé publique, Champs électriques et magnétiques statiques http://www.who.int/peh-emf/publications/facts/fs299/fr/

Association Française pour l'Information Scientifique, Science… & pseudo-sciences. Comment les animaux perçoivent les champs magnétiques
http://www.pseudo-sciences.org/spip.php?article1154