

10 RECOMMENDATIONS FOR NATIONAL AUTHORITIES

It is recommended that national authorities implement programs that protect both the public and workers from any untoward effects of static fields. However, given that the main effect of static electric fields is discomfort from electric discharge to tissues of the body, the protective program could merely be the provision of information about situations that could lead to exposure to large electric fields and how to avoid them.

A program is needed to protect against established acute effects of static magnetic fields. Because insufficient information is currently available on possible long-term or delayed effects of exposure, cost-effective precautionary measures may be needed to limit exposures of workers and the public. Basic protective measures needed to avoid direct and ancillary effects of exposure, and information on exposure standards, form the main protective measures for people exposed to strong static magnetic fields.

National authority recommendations are reported below:

10.1 Exposure guidelines and standards

National authorities should adopt standards based on sound science that limit the exposure of people to static magnetic fields. Implementation of health-based standards provides the primary protective measure for workers and the public.

International standards exist for static magnetic fields (ICNIRP, 1994) and are described in Appendix 1. However, WHO recommends that these be reviewed in light of more recent evidence from the scientific literature.

10.2 Device standards

WHO urges technical standards bodies to continue the development of appropriate technical standards related to the design and manufacture of devices that use static magnetic fields, especially MRI units.

To ensure patient safety, standards should continue to be updated on MRI compatibility of medical implanted devices (see: <http://www.astm.org/>).

10.3 Protective measures and ancillary hazards

National authorities should establish or complement existing programs that provide protection against possible effects from exposure to static magnetic fields. As described below, protective measures for the industrial and scientific use of magnetic fields can be categorized as engineering design controls, the use of separation distance, and

administrative controls. Another general category of hazard control measures, namely personal protective equipment (e.g., special garments and face masks), is not effective for magnetic fields.

Protective measures against the ancillary hazards from magnetic interference with surgical and dental implants or with emergency or medical electronic equipment are a special area of concern. In addition, the mechanical forces imparted to ferromagnetic implants and loose ferromagnetic objects in high-field facilities also require that precautions be taken.

The techniques to prevent needless exposure to high intensity magnetic fields generally fall into three categories, namely,

(a) **Distance and time**

This entails limiting human access to and/or length of occupancy in locations where field strengths may pose a significant risk. Since the external magnetic flux density decreases with distance from the source, separation distance is a fundamental protective measure. For example, at large distances from a static magnetic field dipole source (i.e. distance \gg diameter of source), the field decreases approximately as the reciprocal of the cube of the separation distance.

(b) **Magnetic shielding**

The use of ferromagnetic core materials restricts the spatial extent of external flux lines of a magnetic device. External enclosures of ferromagnetic materials can also 'capture' flux lines and reduce external flux densities. However, shielding is normally an expensive control measure and of limited use for scientific instruments. Furthermore, it has not generally been shown to be cost-effective when compared with the use of separation distance for large installations (Hassenzahl et al., 2004).

(c) **Administrative measures**

There are a number of administrative measures that can lead to significant reductions in exposure to magnetic fields:

- pre-employment or pre-placement medical examinations are needed to ensure that any prospective staff member has no medical condition that would preclude working around strong magnetic fields, or has no implanted medical devices or metallic implants that could be affected by the magnetic field and lead to some adverse health outcome;
- educational programs for staff who need to work around static magnetic fields are needed so that they can have the information necessary to minimize their exposure and be able to work safely around strong magnetic fields;

- warning signs should be posted and special access areas identified to limit exposure of personnel near strong magnet facilities;
- loose ferromagnetic and paramagnetic objects can be converted into dangerous missiles when subjected to magnetic field gradients. Avoidance of this hazard can only be achieved by removing loose metallic objects from the area of the magnet and from personnel;
- in some circumstances, for example in MRI facilities, a combination of shielding, restricted access, and the use of metal detectors may be appropriate to avoid detrimental effects from exposure to magnetic fields.

10.4 Ancillary hazards: implantable medical devices

Electromagnetic interference (EMI) with the normal functioning of pacemakers and other implantable medical devices, and the physical forces on these and other implanted metal objects such as aneurysm clips, etc. are of particular concern in MRI. Certain types of cardiac pacemakers exhibit malfunctions in response to EMI.

Pacemaker malfunctions can also be caused by MRI static magnetic fields, which produce closure of a reed relay switch used to test the pacemaker's performance while operating in a fixed rate pacing mode.

This indicates a requirement for effective controls to prevent patients bearing medical implants from being adversely affected by the fields present in MRI devices.

In addition, possible effects of fields on medical implants should be addressed by competent technical bodies.

10.5 Optimal performance of workers in static magnetic fields

Movement-induced electric potentials and related effects during physical movement within static magnetic field gradients could lead to induced sensations of vertigo and nausea, phosphenes and metallic taste in the mouth, as well as possible effect on eye-hand coordination and near visual contrast sensitivity.

These effects can occur during body or head movement within the magnetic field, thereby having a possible negative influence on the performance of workers during critical procedures at that time. This also poses a potential safety risk.

Steps that can be taken to mitigate these effects should focus on general recommendations to move slowly and to limit sudden head movements, and on awareness notification and training.

10.6 Precautionary measures

Since there is still considerable uncertainty in the available information about possible health effects from exposure to static magnetic fields, national authorities might want to consider implementing precautionary measures that ensure that peoples' exposures are well below the standards. However, such precautionary measures should not undermine the scientific base of the limits by arbitrary reductions in the limits values. Rather, various engineering, administrative and work practice measures should be considered.

WHO is developing a precautionary framework for the reasonable and cost-effective development of precautionary options. Readers should refer to: www.who.int/emf for the latest version of this framework.

10.7 Patient exposure to MRI

WHO recognizes the benefit received by patients undergoing magnetic resonance procedures. However, the static magnetic and other fields to which the patient is exposed are greatly in excess of those normally encountered by the general public or by workers. WHO therefore recommends that patients (and volunteers) undergoing such procedures should be informed of the nature of the associated benefits and risks. The risks are those associated with the direct effects of the fields on the body, as reviewed and assessed in this document, and those associated with indirect effects such as the electromagnetic interference on implanted medical devices and the movement of metal objects in the body.

10.8 Protection program

The American College of Radiology has published a comprehensive set of safety and protective measures for working in MRI units and for patient management (Kanal et al., 2002). These should be implemented as part of a basic protective program for MRI units.

10.9 Licensing

National authorities should consider licensing MRI units in order to ensure that protective measures are implemented. This would also allow additional requirements to be complied with for MRI units with strengths in excess of local national standards or 2 T. Such requirements relate to provision of information on patients and workers, and any incidents or injuries resulting from the strong magnetic fields.

10.10 Research

Given the large gaps in knowledge that pertain to the safety of people exposed to static magnetic fields, national authorities should fund research to fill these gaps. Recommendations for further research form

part of this document and are posted on the WHO web site: www.who.int/emf. Researchers should be funded to conduct studies recommended in this WHO research agenda.

Since higher and higher magnetic field strengths are being introduced, and little scientific information is available regarding their safety, it is recommended that national authorities fund MRI units to:

- collect information on worker exposure to static magnetic fields and make it available for epidemiological studies;
- collect information on patients subjected to MRI procedures. This information should be in a form useful for future epidemiological studies;
- require that facilities operating MRI units collect and provide, to a central agency, any information on incidents and injuries that result from use of MRI units with strengths in excess of 3 T.

National authorities should fund databases collecting information on exposures to workers where high long-term exposures occur, such as those involved in the manufacture of MRI or similarly high strength magnets, and new technologies such as MagLev trains.