Low-frequency electrical and magnetic fields - the precautionary principle for national authorities - guidance for decision-makers

This publication is intended as support for decision makers, when making decisions on health hazards and electromagnetic fields. It has been based on joint consultations between the National Board of Occupational Safety and Health, the National Board of Housing, Building and Planning, the National Electrical Safety Board, the National Board of Health and Welfare and the National Radiation Protection Institute, on the strength of scientific findings hitherto, at the same time as technical and economic aspects of possible measures are considered in the light of limited community resources. The national authorities recommend a precautionary principle based primarily on non-discountable cancer risks. Similar precautionary principles should also be applied to other suspected effects on health. This guide offers supportive documentation to decision-makers' tasks with assessing what is reasonable in each individual case, balancing possible hazards against technical and economic considerations.

There are no research findings to justify limit values, but there is reason to be cautious

The research findings presented hitherto afford no basis for and cannot be said to justify any limit values or other compulsory restrictions on low-frequency electrical and magnetic fields. The limit values which we have today for high-frequency electromagnetic fields afford protection against thermal effects. In the case of low-frequency fields, we do not know which properties may possibly entail hazards, nor do we know how doses are to be evaluated. If the fields are harmful to health, are the hazards mainly connected with brief, intense exposures or with prolonged, low-level ones? Or is it perhaps widely fluctuating fields that cause the problems? We do not know, but even so we have come to believe that a certain amount of caution may be justified where exposure to low-frequency magnetic fields is concerned.

Precautionary strategy possible

The Criteria Group of the National Institute for Working Life (1995) has observed that the scientific foundations for limit values on magnetic fields are insufficient but that action based on some form of precautionary strategy ought to be possible. In the Group's opinion, however, action of this kind entailed socio-economic considerations which it considered to be beyond the bounds of its mandate. In the USA, researchers at Carnegie Mellon University, Pittsburg, have formulated an approach to magnetic fields problems which they have termed "prudent avoidance". They argue that, as long as our knowledge of the connection between health hazard and exposure remains incomplete, society cannot resort to expensive, peremptory measures. On the other hand, given reasonably strong suspicions of effects on health, one should still take steps which do not in themselves entail heavy expenditure or other inconvenience. A similar approach has been advocated, for example, in the preparatory work of both the Radiation Act and the Health Protection Act, to the effect that suspicion, on firm scientific grounds, of injury risks must
in itself constitute sufficient grounds for implementing the enactments. Most of the authorities responsible for the present publication recommended, in 1994 in a brochure entitled "Magnetic fields and possible risks to health as known in May 1994", that a certain degree of caution should be observed in urban planning and construction if this could be done at reasonable expense.

**The national authorities recommend caution**

The national authorities join in recommending the following precautionary principle: *If measures generally reducing exposure can be taken at reasonable expense and with reasonable consequences in all other respects, an effort should be made to reduce fields radically deviating from what could be deemed normal in the environment concerned.*

Where new electrical installations and buildings are concerned, efforts should be made already at the planning stage to design and position them in such a way that exposure is limited. The overriding purpose of the precautionary principle is eventually to reduce exposure to magnetic fields in our surroundings, so as to reduce the risk of injury to human beings.

**What is meant by a normal magnetic field level?**

"The magnetic field level in the environment concerned" refers to the magnetic field level in areas where human beings can be expected to be repeatedly present for a considerable length of time, e.g. housing, schools, day nurseries and workplaces. "Normal magnetic field level" refers to the average obtained, after calculation or several measurements, for the magnetic field in the surroundings concerned and in conditions which can be taken to reflect the field level over a long period. Measurements close to specific sources with rapidly decaying fields shall not be deemed to reflect the magnetic field level unless individuals can be expected to be present close to the specific source for a large part of the day or working day. Measurement must take place at a sufficient number of points in the space in order to obtain a fair picture of the magnetic field level, and at a sufficient number of points in time in order for the result to be reproducible. Documentation of the measuring methods is important. Where power lines are concerned, field calculations may very often be preferable to measurements. As a general rule magnetic fields in homes and day nurseries far away from power lines are very low. The median value for homes and day nurseries in major towns or cities is approximately 0.1 μT (microtesla). The values in smaller towns and rural areas are approximately half this. In metropolitan regions, about 10 per cent of homes have at least one room with a magnetic field exceeding 0.2 μT. Close to power transmission lines and transformer stations, the magnetic fields are higher. Right underneath a power line, the figure can be about 10 μT. It is estimated that some 0.5 per cent of the housing stock has a magnetic field exceeding 0.2 μT, owing to the proximity of electric cables of different kinds. Measurements have been carried out for a large number of occupational categories at their places of work. The median value obtained was approximately 0.2 μT. Understandably, there are many industrial environments where values fluctuate considerably. The highest daily average, 1.1 μT, was obtained for welders. Levels of hundreds of μT can occur, briefly, where certain individuals or working situations are concerned.

**Some benchmarks for expenditure per fatality/casualty avoided**

<table>
<thead>
<tr>
<th>HAZARD</th>
<th>AUTHORITY</th>
<th>EXPENDITURE</th>
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</thead>
<tbody>
<tr>
<td>Traffic death</td>
<td>Road Administration</td>
<td>MSEK 7</td>
</tr>
<tr>
<td>Cancer from ionising radiation</td>
<td>The Nordic Radiation Protection Authorities</td>
<td>MSEK 12</td>
</tr>
<tr>
<td>Lung cancer from radon</td>
<td>The National Board of Health and Welfare</td>
<td>MSEK 2</td>
</tr>
</tbody>
</table>
What is "reasonable expense"?

A human life cannot be valued in money, but even so it will be readily understood that there are many situations where the possibilities for society or individual persons to save lives or avert serious illness are limited by lack of resources. Resource constraints are an inescapable fact and do not reflect any desire to put a price tag on people's lives. The amount which society is ready to pay in order to save a "statistical life" varies a great deal from one sector of society to another and from one risk factor to another. One reasonable approach would seem to be for protective measures to be ranked according to their benefit in relation to their cost, but this is not always the practice. In certain cases there are great differences between declared ambitions and practical measures taken. The above table is based on known conditions a couple of years ago and reflects the data on which the national authorities were then able to base their priorities. Similar tables from the USA show values between MSEK 5 and 50, with the highest figures emanating from nuclear power and the environment protection and the lowest ones from the traffic sector. In several of the fields mentioned above, the causal relations have been made clear, the risks are well known and the effects of funding inputs are calculable or quantifiable. In the field of radiation protection, measures against ionising radiation costing less than MSEK 5 per statistical case avoided are looked on as urgently necessary.

Medical background

Health hazards feared from exposure to low-frequency electrical and magnetic fields have been under discussion since at least the beginning of the 1980s. The main apprehensions have concerned the risk of cancer, pregnancy disturbances (foetal lesions) and so-called electrical hypersensitivity. The debate has at times been both intense and acrid. One reason for this is that still very little is known about the ways in which human beings and other living creatures are affected by electrical and magnetic fields. The results presented by different research groups have sometimes been contradictory. Contrary to what is the case, for example, with chemical substances and ionising radiation, it has been difficult so far to discover harmful effects experimentally even at very high levels of exposure to electrical or magnetic fields. The best-known effects are thermal effects from exposure to high-frequency electromagnetic fields and the effects of the currents induced by low-frequency magnetic fields. In these cases, however, the field strengths are greater than those for presumed, but unconfirmed, connections between cancer, foetal lesions and electrical hypersensitivity and the fields referred to. Very little indeed is known about the possible biological effects of low-strength fields. The dominant sources of exposure to low-frequency magnetic fields are power lines, installations and electrical equipment. At the same time as the fields may conceivably pose a threat to our health, without electricity modern society would come to a standstill, so it is absolutely essential that both risk assessment and protective measures be based on knowledge and sense and that they should be properly thought out. In January 1995 a group of experts appointed by the National Board of Health and Welfare presented a scientific evaluation of all published research reports in this field. An international group of experts, commissioned by the WHO, has evaluated the state of research concerning the risk of cancer and pregnancy disturbances. In October 1995 the Criteria Group of the National Institute for Working Life presented supportive data for possible limit values, following an evaluation of the cancer risks.

Some studies suggest connections with certain forms of cancer

There are a large number of epidemiological studies in which statistical methods have been applied to connections between illness and an environmental factor, for example in order to see
whether there may be a connection between exposure and magnetic fields and elevated risk of cancer. Where exposures in the working environment are concerned, the main focus of attention has been on the risks of certain forms of leukaemia and brain tumour. For exposure in the dwelling environment, the main concern has been with leukaemia risks to children. The results contain many points of uncertainty. For example, different scientific reports indicate excess risks of completely different kinds of cancer. Nor are there any convincingly accepted connections between dose and the magnitude of risk. Epidemiological studies imply the analysis of a statistical connection between exposure and disease. A statistical connection does not mean that the exposure causes the disease, and so often the results of the epidemiological studies have to be verified through experimental studies, which tell us about possible mechanisms of harmful influence, and through animal studies, in which exposure to the suspected carcinogenic factor is isolated. So far, studies of this kind have not yielded any results to corroborate suspicions of cancer risks or other health hazards from these fields. The above mentioned groups of experts all come to the conclusion that exposure to low-frequency magnetic fields cannot be convincingly shown to entail elevated risks of cancer. Certain epidemiological studies, however, provide some cause for suspecting that there may be a connection with particular forms of cancer. In this connection, it is also important to know that cancer is a disease attributed to a whole combination of factors, by far the most important risk factors among them being diet and smoking. The Swedish Cancer Committee, analysing the causes of cancer in Sweden, has arrived at the results presented in the table below. The results of the studies which have been undertaken show that if exposure to electrical and magnetic fields contributes to the occurrence of cancer, the possible risks of developing cancer are small compared with other risk factors. Every year in Sweden, about 40,000 people develop cancer. According to some estimates, not more than about 100 of these cases might be related to exposure to magnetic fields.

Some causes of cancer in Sweden according to the Cancer Committee (SOU 1984:67)

<table>
<thead>
<tr>
<th>CAUSAL FACTOR</th>
<th>PERCENTAGE OF TOTAL INCIDENCE* IN SWEDEN</th>
</tr>
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<tbody>
<tr>
<td>Dietary factors</td>
<td>30 %</td>
</tr>
<tr>
<td>Smoking</td>
<td>15 %</td>
</tr>
<tr>
<td>UV and other ionising radiation (mainly solar irradiation and radon)</td>
<td>8 %</td>
</tr>
<tr>
<td>Work environment factors</td>
<td>2 %</td>
</tr>
<tr>
<td>General air pollution</td>
<td>1 %</td>
</tr>
</tbody>
</table>

*Incidence = morbidity rate, i.e. the percentage of individuals falling ill or the percentage of new cases of a disease occurring in a population during a certain period of time.

Number of child leukaemia cases unchanged - skin cancer on the increase

Child leukaemia is one of the forms of cancer about which there has been most discussion. The number of children developing leukaemia in Sweden has remained constant over the past 30 years, at the same time as total electricity consumption has multiplied several times over. Domestic electricity use has multiplied tenfold during the same period. Certain other forms of cancer show a numerical increase, skin cancer most of all. In 1992, some 3,500 Swedes developed skin cancer, and of these 1,300 contracted the serious form known as malignant melanoma. UV solar radiation is known to be a very important cause.
No connections with miscarriages or foetal lesions

The debate on risks in connection with pregnancy also began in Sweden about 15 years ago, when it was triggered by office computerisation. Clusters of miscarriages were reported from certain workplaces, but these initial suspicions have not been confirmed by systematic epidemiological observation studies. One or two studies hint at a connection, while an overwhelming majority of studies argue against it. Often it has been impossible to distinguish exposure to electrical or magnetic fields from other important factors.

Causes of electrical hypersensitivity disputed - research needed

Persons with electrical hypersensitivity often suffer from skin disorders in the form of flushing, smarting, itching etc. and also, in more serious cases, other symptoms such as fatigue, headache, palpitations of the heart, perspiration and stomach trouble. Symptoms of this kind are common in the Swedish population and can have many causes. But the electrically hypersensitive individual sees a clear connection between the symptoms and proximity to various forms of electrical
equipment or, sometimes, exposure to sunlight. On the other hand, it has not yet proved possible to induce the symptoms in experiments where the electrically hypersensitive individual has not been aware of experimentally induced electrical and magnetic fields being activated. Additional research and evaluation of treatment methods, among other things, are needed in order to improve our knowledge of the causes of symptoms presented by the electrically hypersensitive, and so for the time being we have refrained from issuing any joint, general recommendations on this subject. It is very important, however, that electrically hypersensitive persons should be unconditionally examined by health and medical services, on the basis of their symptoms.

Examples of costing estimates

On average in Sweden and most other industrialised countries, one child in 25,000 per annum develops leukaemia. Although the hypothesis of the connection between the occurrence of child leukaemia and exposure to magnetic fields cannot be deemed scientifically established, the observed risks are presumed valid in our examples. In one Swedish epidemiological survey, it was observed that children living close to power transmission lines ran a 2.7 higher risk of developing leukaemia than those living a long way away from such transmission lines. This figure has also been applied to transformer stations and stray currents in the following examples, for lack of other risk estimates. We also assume a lifetime of 40 years for the measure taken and an interest rate of 4 per cent. On these assumptions, it can be shown that the cost per statistical case avoided will be \( R = 735 \frac{K}{N} \text{ [SEK/case]} \), where \( K \) is the cost of the measure taken and \( N \) the number of individuals whose exposure the measure eliminates. Cost is only slightly affected by the lifetime chosen for the measure if it is long lasting. If the lifetime of the measure is put at 80 years instead of 40, the estimated costs in the examples below will be 17 per cent lower. It is not possible in these examples to make general allowance for the effect of different doses on the number of leukaemia cases. It has to be noted that our examples are only intended to illustrate a calculation model for arriving at a comparison between different costs.

Depending on the circumstances of the individual case, there may be other solutions or bases of economic calculation which are more appropriate. The calculation model deals only with statistical cases, and many people will have to derive benefit from a measure in order for public health to be influenced. The examples show that exposure reduction measures can cost between a couple of million and several hundred million kronor (MSEK) per statistical case of child leukaemia avoided, subject to the risk estimates employed remaining valid. Note that the precautionary principle recommends that measures should be considered when the fields deviate strongly from what can be deemed normal in the environment concerned.

Power line near multi-family dwellings

An existing 220 kV power transmission line crosses a multi-family housing area with 300 children living within a distance of the line where the risk of child leukaemia is presumed to be elevated by proximity to the power line. The cost of replacing the power line with another solution D laying a cable along an existing road is MSEK 60. If this measure is taken, the cost per case avoided, assuming the estimated risk to be true, will be about MSEK 150. Calculations by local authorities may involve other aspects on which a value can be placed, e.g. the fact of land being released for alternative use.

Pre-school near a power line

A day nursery used every day by 40 children is so close to a power transmission line that the risk of child leukaemia can be deemed elevated. The cost of building a new day nursery elsewhere is MSEK 4. If this measure is taken and there are no other economic aspects to be taken into consideration, the cost per case avoided will be MSEK 74. If instead it were possible to use
tuned, screened circuits, at an estimated cost of MSEK 0.5, the cost per case would be about MSEK 9.

**Transformer station in a school building**
A transformer station in a school building causes elevated magnetic fields in three classrooms. One possible means of reducing the magnetic fields is to line the space with sheet metal. A measure of this kind costs about SEK 1,000/m², materials and labour included, which can mean a total cost of about SEK 200,000. Assuming the measure to reduce exposure for 75 children using the classrooms, the cost per case avoided will be less than MSEK 2.

**Stray currents in single-family dwellings**
A single-family dwelling has elevated magnetic fields which are presumed to augment the risk of child leukaemia. These magnetic fields are caused by stray currents from installations in the house, and these currents will cost SEK 5,000 to eliminate. Assuming that there will be, on average, one child living in the home over a period of 40 years, the cost per statistical case avoided would be about MSEK 4.

**Power line in rural area**
A 400 kV power transmission line is planned in a rural area. An effort has been made at the planning stage to locate the line as favourably as possible, e.g. from the viewpoint of persons living close by. It is intended to use a power line structure, a T-pole, which is more advantageous from a magnetic field viewpoint than the traditional transmission line structure. These measures can be taken without any appreciable added expense or other consequences. Even so, for 80 km of its length the line will pass within such a distance of 71 scattered properties that the magnetic fields in the properties can be deemed elevated. With a view to reducing the fields locally on each property, the possibility is being investigated of using tuned screened circuits. Every such circuit costs an estimated MSEK 0.5. Assuming that, on average, there is one child living on each property and there are no other economic aspects to be taken into consideration, the cost per case avoided will be about MSEK 370. The cost per case will be the same if it is preferred to purchase the properties for an average of MSEK 0.5 each.

**Power line planned through suburban area**
A 220 kV power transmission line is planned through a suburban area. The line will pass a multi-family dwelling within a distance at which it can be deemed to elevate the risk of child leukaemia. There are 60 children living in the building. To avoid an elevated magnetic field, it is planned to splice a split-phase line into the section which passes the building. The additional cost entailed by this solution is estimated at MSEK 0.7. If the measure is taken, the cost per case avoided will be about MSEK 9.
Some further reading

3. Floderus B, Persson T, Stenlund C: Lågfrekventa magnetfält i arbetsmiljön. Referensvärden och exponering i olika yrkesgrupper. Arbete och Hälsa 1995:1. (Low-frequency magnetic fields in the working environment. Reference values and exposure in various occupational categories)

(The above titles are available in Swedish only)

Copies of this guide are available from the following participating authorities:

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