Draft for the Precautionary Principle Workshop

1. Introduction

The Precautionary Principle

" We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology."

This observation by Carl Sagan helps explain why scientific and technical innovations can be both welcomed and feared, often by the same people; and why the pace of technological change, like a roller-coaster ride, can generate excitement and fear in equal measure. Indeed there have been few technical developments so benign as not to be accompanied by some risk. By passing laws and promoting cautionary advice society tries to minimize these risks, while still enjoying the benefits. In making this risk-benefit trade-off society is guided by its culture, its traditions, its experience and its scientists. This arrangement works well when there has been time for experience to accumulate and scientists are trusted. When, however, the risk is a new one, where its impact cannot be gauged, and where trust in science has declined, we enter the province of the Precautionary Principle.

The Precautionary Principle is intended to prevent or limit the possible harm caused by agents or activities before it has been established that the activity or exposure constitutes a harm to health. As threats to human health and the environment become more complex, uncertain, and global in their nature and while recognising that injudicious measures could lead to disruptions to trade and other unanticipated costs, the value of adopting the Precautionary Principle as a risk management tool in providing guidance in this environment is under active debate[1].

Possible health effects arising from exposure to extremely low frequency (ELF) electromagnetic fields (EMF) have been the subject of research for many years, but without definitive scientific resolution. At radio frequencies (RF), the rapid growth of new technologies such as mobile wireless telecommunications has raised concerns that exposure to fields from mobile phones and base stations could have long-term health consequences.

Given the widespread exposure of the general public and of workers to ELF and RF fields, this workshop will focus on these regions of the non-ionizing frequency spectrum as candidates for application of the Precautionary Principle. The two key questions are:

- Should the Precautionary Principle be invoked for ELF and/or RF fields?

- If so, how do we decide what actions should be taken?

The workshop

The aims of the workshop are threefold:

- ***to arrive at a common framework for the Precautionary Principle,***

- ***to apply this framework to human health effects from exposure to electromagnetic fields and specifically to develop two case studies for ELF and RF fields, and***
- ***to recommend risk management approaches for ELF and RF fields.***

The workshop brings together scientists, engineers, lawyers, health professionals and concerned citizens with knowledge of the Precautionary Principle to contribute perspectives from health, government, academia, environmental advocacy groups and industry. The European Commission text, published in 2000, has been used as one of the key starting points for this Working Group report on the application of the Precautionary Principle [2].

> *Outputs of the workshop will include the proceedings, containing all of the presentations given at the open session, and a scientific article summarizing the results and conclusions of the working group meeting. In addition, the meeting results will contribute to the WHO International EMF Project's development of policy options for EMF, and to general WHO policy on the use of Precautionary Principle on health issues.*

2. Objectives of the Precautionary Principle

Protecting public health

When developing policies and actions to protect public health it is important that the definition of health is clearly stated. WHO defines **health** as a *state of complete physical, mental and social well being and not merely the absence of disease or infirmity.* Public health policies have always had measures aimed at disease prevention. These measures can be extended to include potential risk factors that have not yet been established as the cause of the effect or where much uncertainty remains. In this way the Precautionary Principle can be naturally integrated within public health policy and actions.

> ***The Precautionary Principle is***
>
> ***a risk management concept that provides a flexible approach to identifying and managing possible adverse consequences to human health even when it has not been established that the activity or exposure constitutes harm to health.***

Objectives of the Precautionary Principle in health policies

There are three important reasons to invoke the Precautionary Principle within a public health policy:

- to be more anticipatory in terms of health and dealing with unknowns,
- to address public concern, which may be more directed at ensuring a potential problem is not ignored, in contrast to scientists who are often reluctant to give credibility to unproven possibilities. The Precautionary Principle can provide a framework within which these different positions can be reconciled.
- to provide an alternative to exclusively technology-based environmental management, in order to bring ethics into the discussion and give environmental

rights a voice. The Precautionary Principle may also challenge the singularity of strictly financial cost-benefit analysis as a decision-making tool.

While appropriate action should be taken even when there is lack of scientific certainty, this does not necessarily mean that precautionary measures are required or justifiable when there is no particular evidence, scientific or otherwise, of the presence of possible harm.

The Precautionary Principle represents an anticipatory approach by nature, and precautionary measures have to be viewed as provisional (or temporary) rather than permanent, i.e. it should be subject to review in the light of new scientific findings.

Balance between scientific and social considerations

The Precautionary Principle is a risk management tool that is complex in its application. This complexity depends on the degree of scientific uncertainty, the potential severity of harm and the interplay between science and social factors. Risk is a complex social construct and its many facets can lead to different responses by individuals and to diverse reactions by the various stakeholders to the proposed risk-management options. The general public and scientists differ in their willingness to make a mistake about the existence of risk. Scientists usually require considerable certainty before accepting that a risk is real. This attitude is embodied in hypothesis testing used to evaluate statistically whether a risk is real or not. Conceptually, scientists will normally support a positive association (i.e. the risk is real) if the probability that the risk has arisen by chance is below 5%. Scientists are also often willing to 'miss' a real association (i.e. conclude the risk does not exist, when it actually does) with a probability of 20%. The public, however, is more concerned that any potential hazard or risk is not overlooked, irrespective of statistics. The Precautionary Principle needs to recognise these issues, and whilst remaining based on scientific evidence, must recognise the validity of social concerns as well.

Relation between Exposure Standards and the Precautionary Principle

All international and nearly all national guidelines limiting human exposure to EMF are based on health effects established by research results that are consistent, reproducible and confirmed by different laboratories. In addition, the exposure limits and guidelines incorporate safety factors to allow for some of the uncertainty in the thresholds for these established effects.

Thus, broadly speaking, Exposure Standards apply where there is scientific certainty, whereas the Precautionary Principle applies where there is uncertainty. The two should not be in conflict. The Precautionary Principle can provide a helpful framework to allow possibilities to be considered which would be excluded from the approach employed to develop traditional exposure limits. Nonetheless, where international guidelines exist, it is important that the application of the Precautionary Principle does not undermine the scientific basis of the limits.

Different ways of deciding on precautionary actions

It is worth repeating that the objective of applying the Precautionary Principle is to deliver appropriate protective measures against uncertain hazards. Just as is the case with established hazards, the protective actions must be appropriate and proportionate. Not all established hazards are important enough to justify regulation. Even in dealing with established hazards, there has to be a weighing-up of the benefits and the costs of regulation. These costs will usually include ones that cannot be quantified easily in money terms (e.g. the value of a life). These factors apply equally when considering the precautionary actions to be taken in relation to uncertain hazards.

Central to the application of the precautionary principle presented here is a balancing of the consequences and benefits. This is conventionally referred to as cost-benefit analysis. Later sections discuss how "cost" is used in a wider sense than just financial. Nor does a cost-benefit analysis imply that the approach taken is purely utilitarian. Issues of social justice between individuals and communities, and ethical factors such as whether exposure is voluntary or involuntary, are also included. What is advanced here is an approach that allows all these different facets of health protection to be accommodated in a framework that nonetheless allows objective and defensible decisions to be made.

Precautionary approaches to EMF have already been advocated and adopted in various countries. These have rarely involved an adequate balancing of consequences and benefits. Instead, most existing approaches have tended either to specify the costs to be incurred, without balancing these costs against the benefits, or to set out the intended benefits without regard to their cost.

Examples of approaches that specify costs without placing a value on the benefits include:

- Requiring a certain percentage levy on the cost of a project to be spent on EMF mitigation measures, as has happened with some new transmission line projects
- Requiring a fixed sum to be spent on EMF mitigation in a defined situation, such as providing money to schools to be used to reduce exposures
- Advocating a variety of low-cost measures to reduce emissions or public exposures to EMF

Examples of approaches that, on the other hand, provide defined benefits without regard to costs include:

- Setting precautionary exposure limits (e.g. 1 μT or 0.5 μT)
- Advocating measures to reduce exposures (e.g. time limits on use of mobile phones or restrictions on children's use of phones)
- Requiring exposures to be reduced by a stated amount or percentage compared to what they would have been previously
- Requiring exposures to be no higher than those already existing in an area
- Requiring use of best-available technology to reduce or minimize exposures

These examples of ways employed to reduce public exposure to EMF can be described as measures which reflect the policy of "prudent avoidance". "Prudent avoidance" is an umbrella term for approaches that favour taking whatever field-reduction measures may be possible subject to the cost being financially “modest”. Prudent avoidance therefore fits in the category of setting (modest) costs without valuing or quantifying the benefits.

These approaches can not be completely satisfactory, as none properly weigh up or balances costs and benefits. With some of these schemes, costs and benefits are weighed implicitly rather than to a specific individual situation. For example, a decision to recommend 4% as an appropriate fraction of project cost to be applied to EMF reduction, could in principle be the result of a balancing of costs and benefits. However, this balancing, if done at all, could only have been done in a general way, averaged over many projects. There would be particular projects where 4% of the project cost could yield huge reductions in exposures and others where little reduction, if any, is possible. Thus, whilst each of these approaches may at times be able to generate the appropriate precautionary actions, there would also be situations where each generates inappropriate actions, and are therefore unsatisfactory.

Once a correct and full application of the Precautionary Principle has been achieved it is recognized that there may be value in expressing conclusions in a form that makes them readily applicable to practical situations. Such simplified “action rules” could look similar to some of the existing schemes listed above, but would differ in that (a) they would apply only to the limited and specified range of circumstances for which they are valid, and (b) they would follow from the full application of the Precautionary Principle, rather than reflect some arbitrary position.

As an example of “action rules”, a new proposed Charter between city halls and mobile phone operators has been developed by the French government [3] for improved management of new mobile phone mast installations. A number of administrative actions are initiated, based on criteria designed to evaluate the impact of a new base station, which include technical details concerning location (e.g. distance to urban areas, proximity to school) and social impact (e.g. aesthetics and public reaction).

3. When to apply the Precautionary Principle

Risks are present in all aspects of our lives, and there will always be some uncertainty associated with those risks. As individuals and as a society we regularly make decisions under uncertainty, without a full knowledge of the extent of the risk. While the possibility of risk does not in itself require action, uncertainty in itself does not justify inaction. The question then is: “When to act?” What **strength of evidence** is required to trigger action or invoke the Precautionary Principle? (e.g. a possible cause, no conclusive scientific proof, or sufficient evidence).

Risk Analysis

The analysis of risk encompasses three main elements, namely risk assessment, risk management and risk perception. Within this framework, the Precautionary Principle is relevant when considering the range of **risk management** options available. To be effective it must take into account both measured and perceived risk.

Several factors add to the public’s perception of risk, and increase the potential for concern. The following factors, developed in a German report [4], are expanded and adapted here to the EMF issue:

- **Extent of damage**: Adverse effects can be quantified in different ways, depending on the end-point considered (e.g. in terms of number of lives lost to cancer, or production losses from electrically hypersensitive (EHS) people who cannot work due to their condition).
- **Probability of occurrence**: The existence of a potential adverse effect from an environmental exposure could trigger the Precautionary Principle. Knowledge of the probability of the adverse effect as a function of the level of exposure greatly enhances decisions; these probabilities are one of the most uncertain aspects of risk assessment, especially for EMF.
- **Uncertainty**: Uncertainties exist at every level of evaluation, from uncertainty about the presence of a hazard to uncertainty in the levels of exposure a person receives. The relevant metric is the most important uncertainty for the application of the Precautionary Principle to EMF.
- **Ubiquity**: Most common EMF exposures come from the use of cell phones and appliances as well as from electrical wiring in and outside of homes and proximity to mobile phone masts in urban areas. Ubiquity of this exposure is an important driver for the Precautionary Principle.
- **Pattern of Exposure**: In general, pattern of exposure including length, intensity, and fractionation can play a key role in their influence on disease incidence. This could be due to the existence of a threshold, complex dose-response pattern and adaptive response. Potential differences in effects due to low long term exposures from power lines and base stations vs. more intermittent but much higher exposure from appliances and cell phones have been suggested but not adequately examined.
- **Delayed effect**: Latency is the time between the initial exposure and evidence of disease. One of the main diseases of interest is cancer, which has latency from several years to decades. Thus, consideration of latency is important, particularly in the case of cell phones, where ubiquitous exposure is recent and where potential development-of brain cancer might be years away, thus calling for an anticipatory consideration of the Precautionary Principle.
- **Inequity and injustice** associated with the distribution of risks and benefits over time, space and social status (e.g. routing of power lines or erection of base stations in low-income areas)
- **Psychological stress and discomfort** associated with the risk or the sources of risk (e.g. people particularly sensitive to EMF). This has clearly been a driver for the application of the Precautionary Principle to EMF
- **Potential for social conflict and mobilization**: Degree of interest and pressure from advocacy groups and associations. Again, this has occurred with the EMF issue, especially when new facilities such as base stations or power lines are proposed or built.
- **Voluntary vs. involuntary exposure**: People feel differently about risk when the choice is theirs. For EMF, higher exposures from cell phones and appliances have been of less concern to the public than lower but involuntary exposures from base stations and power lines.

Scientific Uncertainty

While the Precautionary Principle applies by definition to situations characterized by scientific uncertainty, its application to the EMF issue is especially problematic, because there is uncertainty not only as to whether exposure is associated with increased risk or not, but also:

- **Uncertainty about the magnitude and specificity of the risk**. The risk from exposure to EMF, if real, could be small but affect a large number of people. Alternatively, the risk could be large but affect only a small number of susceptible individuals. Other possibilities might include simultaneous exposure to another factor. Different possible relationships between risk and exposure may require different precautionary measures to reduce risk, making application of the Precautionary Principle particularly difficult.

- **Uncertainty as to which aspect of exposure might be harmful**. Certain actions, while reducing some aspects of exposure, might inadvertently increase risk by increasing some other, as yet unknown, aspect that might turn out to be the true cause. The concept of precautionary action is often rooted in the assumptions that less exposure is better and that reducing one aspect of exposure will also reduce other aspects that might be harmful. Neither of these assumptions, in the context of electric and magnetic fields, is necessarily valid. In fact, some laboratory research has suggested that biological effects due to EMF can vary within windows of field frequency and intensity. While such a complex and unusual pattern is unlikely and would defy most accepted tenets of toxicology and epidemiology, the possibility that it may be real must be considered when applying the Precautionary Principle to EMF.

  The absence of a clearly elucidated, robust, and reproducible mechanism of interaction of EMF with biological systems and the plethora of field characteristics that could be relevant, make avoidance strategies that fall short of eliminating EMF exposure entirely both difficult to analyze and potentially counterproductive. Complete elimination of exposure could only be accomplished if no one were to use electricity or modern communications technology.

Triggers for the application of the Precautionary Principle to EMF

> The Precautionary Principle should be invoked when:
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> - there is good reason, based on empirical evidence or a plausible causal hypothesis, to believe that harmful effects to people might occur, even if the likelihood of harm is remote; and
> - a scientific evaluation of the consequences and probabilities reveals such uncertainty that it is **not yet possible** to assess the risk with sufficient confidence to inform decision-making.
>
> *adapted from the UK Interdepartmental Liaison Group on Risk Assessment [5]*

There are three factors that might, in general, trigger the application of the precautionary principle:

- Recognition that there is objective scientific evidence that amounted to the possibility of a health risk. This is the situation where (as is the case with ELF magnetic fields) the International Agency for Research on Cancer (IARC) or a body with equivalent status classifies an agent as “possibly carcinogenic” or “possibly” a cause of other forms of ill health. Where there is no such classification, applying this criterion is less objective and less satisfactory.

- A recognition that there may be a very low cost intervention available, in which case an action may be justified even when the scientific evidence is weak, specifically when it is too weak even to be classified as "possible". This is the case for the use of hands-free devices for mobile phones and limiting the amount of time children spend on these phones. This criterion needs to be applied with care to ensure that an apparently "low cost" option really is low cost. In principle, no matter how low the apparent cost of an intervention, at least a rudimentary cost-benefit analysis should be undertaken.
- Public pressure. This would often result in consideration of precautionary actions even in circumstances where the evidence is weak and subjective, but nonetheless must be recognized as a practical consideration.

Note that these are triggers, not for *taking* precautionary action, but for *applying* the Precautionary Principle, that is, for making a detailed assessment of the benefits and consequences of action that may or may not be taken. The Precautionary Principle, when applied properly, should not result in unjustifiable or disproportionate actions. Therefore, in principle, it can be applied no matter how weak the evidence. The reasons for requiring a trigger are pragmatic; applying the Precautionary Principle properly entails much work. There is always the possibility of a superficial application resulting in inappropriate actions. It is therefore sensible not to invoke the Precautionary Principle without adequate justification.

In the EMF context, there is sufficient evidence, judged against these criteria, to invoke the Precautionary Principle both for extremely low frequencies (ELF) and radio-frequency (RF) electromagnetic fields. This conclusion is based on several factors:

- the classification by IARC in 2001 of ELF magnetic fields as a possible carcinogen based on studies of childhood leukaemia
- the comparable radiation levels of existing mobile phones to established international guidelines,
- the availability of some low cost exposure reduction options

Initially, the Precautionary Principle needs to be applied separately to each health end-point being considered, as the calculations and hence conclusions can be quite different. However, once this is completed, the potential benefits accruing from each given exposure reduction need to be aggregated over all the different health outcomes being considered, so as to obtain the overall benefit.

Legal context of the precautionary principle

In some societies or sections of society, there is a reticence to adopt precautionary measures in case this is seen as an admission that the health risk is real. In part, this concern relates to public perception of the issue. This concern can be ameliorated, though not necessarily completely removed, by sensitive communication. In part, however, the concern is legal: that adopting precautionary measures could be construed as an admission of liability; that it might be taken to imply responsibility for similar exposures prior to taking precautionary action; and that it may put the person or company taking such actions in the position of having to justify, in a legal arena, why they took the actions they did and did not go further.

Such concerns about liability and admissions are detrimental to optimum operation of the Precautionary Principle and hence to optimum protection of public health. As far as possible the Precautionary Principle should be implemented in a way that is free from such legal connotations. How this is achieved will depend on the legal and regulatory frameworks of the countries concerned.

4. General Considerations for the Precautionary Principle

Where action is deemed necessary, measures based on the Precautionary Principle should take into consideration a number of application criteria. As set out by the EU (1) the criteria are: proportionality, non-discrimination, consistency, an examination of the benefits and costs of action or lack of action, a review in the light of new scientific developments, and assignment of responsibility for producing the scientific evidence required for a further risk assessment.

As a general criterion, special consideration should be given to precautionary measures for sensitive populations, especially children. This is both because children might be more susceptible to environmental exposures and because of a societal value judgement that children deserve greater protection. In quantitative risk assessment additional "safety" or "uncertainty" factors are invoked for children and, in absence of data to the contrary, should be applied in the same way for exposures to ELF and RF.

Proportionality

"Proportionality" means tailoring to the chosen level of protection. Risk can rarely be reduced to zero, and a total ban will not be a proportional response to a potential risk in all cases. The range of options are given in Figure 1(adapted from [6]).

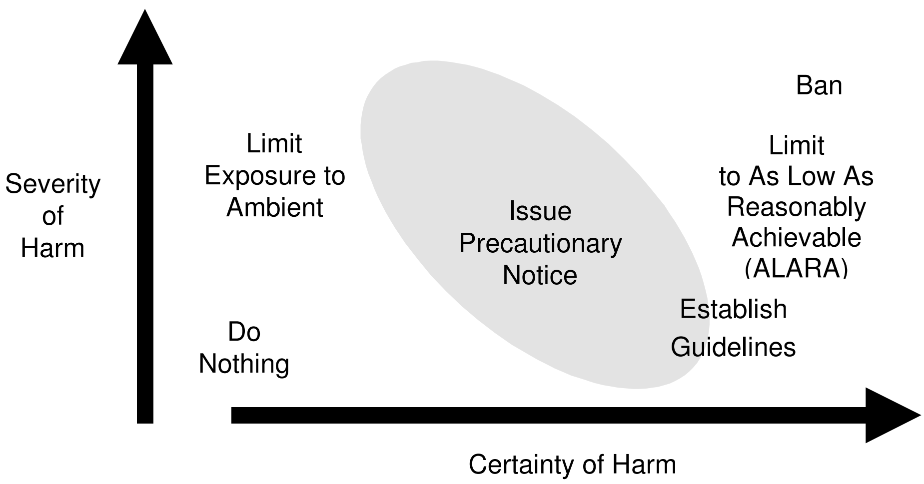

Figure 1 - Range of actions under uncertainty. The shaded area shows combinations of severity and certainty of harm for which the precautionary principle may be useful.

In the final analysis, the chosen level of protection will be a political decision that will depend on many factors, among them the nature of the adverse health effects being considered.

Non-discriminatory

"Non-discriminatory" means that comparable situations should not be treated differently, and that different situations should not be treated in the same way, unless there are objective grounds for doing so. Exposures to ELF come from multiple sources that are often the responsibility of different organizations. Radio-frequency exposures come from all radio transmitters, including TV and radio, as well as mobile phone handsets and base stations. All such sources of exposure should be given equal consideration. While it may still be legitimate to decide to implement interventions that affect one source and not others, this is only justifiable following a fair process of assessment, and not simply the consequence of administrative convenience, political expedience, or public relations.

In the absence of information to the contrary, one must assume that biological effects due to EMF exposure do not differ between countries. Therefore, any precautionary measures should be considered equally in different countries, although the conclusions reached may well differ as a result of different philosophies, priorities and costs involved.

Consistency

"Consistency" means that the measures should be of comparable scope and nature to those already taken in equivalent areas where all scientific data are available. Most societies have frameworks for deciding when and how to intervene when dealing with established risks. The Precautionary Principle should not be used to justify actions beyond those that would be taken for an established risk. In many developed societies, a known risk of cancer to an individual member of the public greater than one in ten thousand per year would usually be subject to regulatory action. Actions taken for more subjective outcomes such as headaches or sleeplessness are less quantified.

The benefits and costs of action or inaction

Examining the benefits and costs of action or lack of action requires an estimate of the overall cost to the community in both the short and long term. This is not simply a narrow economic cost-benefit analysis: its scope is much broader, and includes non-economic considerations, such as the efficacy of possible options and their acceptability to the public. However, given that economic costs, non-economic consequences, and health effects are quite disparate concepts, some common measure must be adopted to allow comparisons. The only realistic method is to equate all consequences and benefits to a financial quantity such as money, **recognizing that this is only to facilitate the comparisons of options and does not imply that all consequences can actually be reduced to financial values**. In the conduct of such an examination, due account should be taken of the general principle that protection of health takes precedence over economic considerations. This is discussed in greater detail in Section 5.

Subject to review

Precautionary measures should be temporary: they apply only for as long as scientific uncertainty persists. They should therefore be periodically reviewed in the light of scientific progress, and amended as necessary. Thus continuing scientific research is often needed and cost-effective.

Capable of assigning responsibility

A corollary to the need to review precautionary measures periodically to see if they are still justified by the state of scientific uncertainty is that responsibility should be assigned for gaining new scientific knowledge and for reviewing it. Industry and Government should share the responsibility for reducing uncertainty, because the benefits of reducing uncertainty would not be limited to the industry. Furthermore, shared responsibility is likely to lead to a more focused and credible research. It is often efficient to pool resources to fund research and have it managed by an independent institution. There are several successful examples of this shared effort in the EMF area. As additional scientific information~~,~~ becomes available, individuals and industry may change their behaviour, while the responsible government department could make recommendations on whether to amend any precautionary measures that have been put in place.

5. Developing a comprehensive action plan

Identify possible actions under the Precautionary Principle

Generally speaking, there will be a sequence of possible actions under the Precautionary Principle~~,~~ which would be invoked successively should the evidence for a health risk emerge. Weak evidence usually justifies communication and information provision; better evidence would warrant a planned and focussed research programme; while strong evidence would justify the introduction of precautionary actions to reduce exposures. Ultimately the issue moves beyond precaution into formal protective exposure controls.

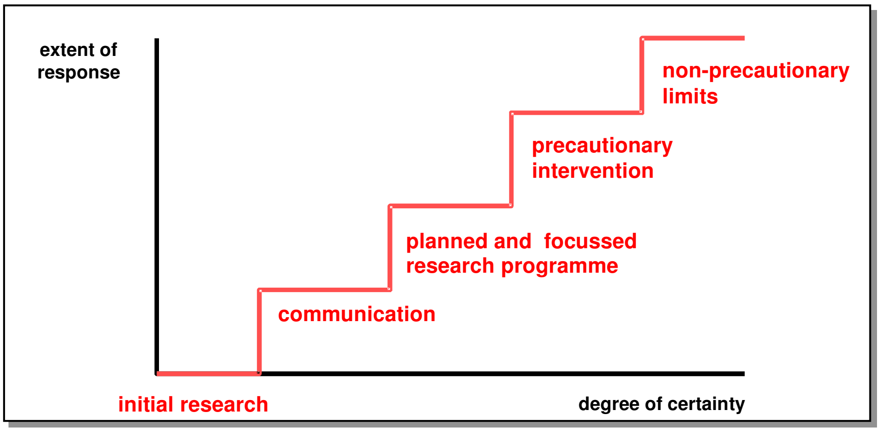

Figure 2 – Extent of response under uncertainty

Action under the Precautionary Principle depends not only on the strength of evidence but also on what potential actions are available.

At one extreme, banning an agent or activity will depend on whether or not an alternative is available. If so, the implications of the alternatives for potential health effects, costs and benefits must be evaluated. Where no alternative is available, the evaluation needs to focus on the benefits provided by the agent or activity against its potential detrimental effects. Clearly, the use of electricity, mobile phones and other goods and devices that produce EMF has clear benefits not only in terms of convenience but also for their positive contributions to health. Forsaking the use of electricity is not a viable option.

Consideration of the Precautionary Principle in the case of EMF therefore must focus on an evaluation of the available options to reduce exposure rather than an elimination of the exposure.

At the other extreme, the option of doing nothing should be also evaluated employing a similar methodology. Although 'doing nothing' is often assumed to be the most benign option, it can incur substantial costs. Increase in public concern and anxiety can produce both adverse health consequences and higher economic costs as illustrated by the current difficulties in rolling out 3G mobile phone technology.

Between these extremes, a range of other actions and interventions needs to be considered. Some will carry minimal costs. For example, the reduction of exposure to EMF from appliances and mobile phones can be achieved through a personal decision to limit use or to reduce proximity to the appliances. To invoke such measures would require less evidence than would be needed for more costly actions.

In some circumstances it may be that actions to minimize the seriousness of the health outcome are viable and should be evaluated as alternatives to actions to reduce exposure.

Each possible intervention needs to be separately identified and assessed. Different considerations apply to different interventions. Likewise, the retrospective application of the same intervention and its application to a new construction also need separate assessment.

For each candidate intervention, assess the costs and consequences

The consequences of an intervention can be broken into three components:

- **Initial cost**: This is the actual cost of implementing the intervention. In the EMF context this is, for example, the cost of burying a power line, moving a service panel, designing a cell phone of lower power, or supplying a hands-free kit.
- **Ongoing cost**: Some interventions will create ongoing costs. For example, a split-phase distribution line may be more expensive to maintain; and an underground power line may have greater electricity loss. Alternatively, the ongoing "costs" may actually constitute financial benefit when the intervention results in plant with a longer life or greater efficiency as a result of newer technology.
- **Consequential costs**: These encompass all remaining costs of the intervention. Again, there may be benefits as well as costs. Consequences to consider include effect on property values, changes to reliability and security of supply, safety consequences from the implementation or operation of the intervention, any further effect on concern or anxiety in the public's willingness to use the modified activity or service, and any legal liabilities created or averted.

As already stated, in order to facilitate comparisons it is necessary to reduce all costs to financial values. It is recognised that this is an imperfect measure. Furthermore, the cost calculations based on current technology tend to be an overestimate as innovation often leads to cheaper solutions when these are needed.

It is assumed that the final assessment of costs and benefits will be performed at the level of a whole society, ideally by Government. It will therefore encompass all costs regardless of who might bear them, be they on industry, electricity users, cell phone users, homeowners, taxpayers or others. Costs always have consequences, not least through the established association between disposable income and health. The proper application of the Precautionary Principle must address those consequences.

For each candidate intervention, assess the putative benefit

At this stage the assumption is that there is actually a health risk. We are now assessing the benefit arising from the elimination or reduction of the health risk under consideration. The uncertainty as to whether the risk actually exists is dealt with later.

There are two stages involved in assessing the putative benefit:

Stage One

Firstly the effect of the intervention under consideration on the exposures is assessed. This can be quite complex. An intervention may have different effects on different aspects of exposure (the risk offset). In the power-frequency context, some interventions will reduce both average and peak exposures, and possibly affect many other exposure parameters as well, though to a different extent. Other interventions may reduce average exposure but increase peak exposure. For cell phones, hands-free devices reduce exposure to the head but may increase exposure to other parts of the body.

Secondly, an intervention may re-distribute exposures among different people or populations (risk transfer). For example, moving a service panel in a school may reduce prolonged exposures to a group of children in one classroom but increase short-term exposures to a larger group of children elsewhere in the school. Even more complex is the choice between building more small base stations in highly populated areas or a lesser number of more powerful transmitters on the outskirts of the cities.

Thirdly, an intervention focused on new facilities might have unintended consequences. If the building of new facilities becomes too expensive, a decision not to build a new power line or link will increase loads and hence EMF in the vicinity of the existing networks. Similarly, the inability to build new mobile phone base stations will increase the traffic at the existing ones. In principle, it is necessary to capture a complete picture an intervention has on the pattern of exposures across the population. In practice, this is never totally possible. However it is important to avoid assuming that the consequences can be adequately expressed in terms of a single number representing reduced exposure.

Stage Two

Firstly, available information on the exposure-response for the health endpoint under consideration should be assessed. Inevitably, given that the Precautionary Principle applies only where there is lack of certainty, there will be uncertainty in this exposure-response relationship that needs to be quantified and carried forward.

It is then possible to combine the impact of the candidate intervention on exposures with the exposure-response to assess the consequences the intervention would have for risk or incidence of disease. Given the uncertainty in the exposure-response relationship, and the different effects an intervention may have on different aspects of exposure, there will also be a degree of uncertainty in the estimate of the reduction in risk. Where an intervention reduces one aspect of exposure whilst increasing another, there may even be a finite probability that an intervention might increase risk rather than reduce it.

The reduction in risk needs to be expressed in units that make clear whether it is per person affected, per member of some defined affected population, or applies to the whole population. In addition, the outcome of interest needs to be clearly specified: for instance, different answers will be obtained if the outcome is defined as number of fatalities, as opposed to disease incidence or to years of life lost. In general, disease incidence is the preferred parameter, provided childhood disease is given appropriate emphasis elsewhere. National governments however could choose to put the emphasis on other measures of the outcome.

Value for the reduction in risk/disease

As already stated, there should be no intent to place an actual financial value on a human life or on disease. However, it is necessary to assign a notional figure to allow comparisons and decisions. In fact, many societies already use figures for the "value of a fatality prevented". This approach is used in assessing highway improvements, for example. This tends to be an empirical figure rather than a principled statement. It is an observation that societies, when faced with competing priorities in the health and safety arena, generally do have to employ a rule of thumb in assessing and prioritising specific proposals.

Because this figure representing the value of a fatality prevented stems from an observation of what societies are prepared to spend money on, it varies with the circumstances. Societies exercise valid value judgements and are prepared to spend more on preventing fatalities where the person concerned has no choice in facing the risk, where the potential fatality affects children, and where the fatality arises from a particularly dreaded disease, such as cancer. Therefore the value a society will attach to preventing a fatality will be more for EMF, where all three criteria apply, than for highway engineering where, essentially, none apply.

Even more difficult is the evaluation of softer outcomes such as headaches and sleeplessness that are reported by some to be associated with living near to base stations. These outcomes are not only difficult to study; their costs to society and individuals are also highly uncertain.

Allow for the uncertainty in whether there actually is a risk or not

The figure derived for the value a society places on the reduction of risk or disease arising from a particular intervention assumes the reduction would actually occur, i.e. there is an established risk. Where, as with application of the Precautionary Principle, the risk may not actually exist, it is necessary to adjust this figure. Conceptually, it becomes necessary to derive a figure for the likelihood that the exposure actually does cause the disease. This likelihood could then be incorporated in the analysis in various ways. The simplest approach is to multiply the benefit (the reduction in risk or disease) by the probability it actually occurs. This purely utilitarian approach should be the starting point, despite its shortcomings.

Compare the costs and benefits

Once measures of the benefits and costs of each candidate intervention are obtained, they can be compared to assess which interventions are justified.

The utilitarian approach would be to reduce exposure until the cost of the last reduction equals its benefit. However, society may wish to err on the side of caution and incur greater costs, in excess of the expected benefit. This may be the case for all risks, but is particularly relevant as an insurance policy against a small risk of a serious consequence, and may apply in particular to circumstances involving involuntary exposure, exposures of children, and to certain diseases. This is a value judgement and is entirely legitimate, and can either be taken into consideration at this stage by making the test for comparing costs and benefits "not disproportionate" rather than "equal" or at the earlier stage of deriving a value for a fatality prevented. Obviously this factor must be included only once and not at both places in the analysis.

While some costs will arise only once, others are on going as, in general, are the benefits. The applied costs and benefits must therefore be discounted using an appropriate model. Any attempt to restrict the comparison of costs and benefits to a fixed time period would be arbitrary and unsatisfactory.

Uncertainties that have arisen at each stage of the process should have been carried forward to this point. Therefore, as well as providing a single answer to the question: "Is this intervention justified?" there will also be a measure of the robustness of this answer. If the uncertainties are considerable, a decision as to whether an intervention is justified may be rather marginal.

6. Discussion

If the application of the Precautionary Principle has been completely logical and rigorous, and if similar logic and rigour apply to all other areas of health and safety, then the answer reached will be the correct one, whether viewed in isolation or when compared to practice elsewhere. However, given that in matters involving human judgement on emotive issues strict logic may not always be followed, it is sensible to apply three "reality checks" to the conclusions reached on those interventions which are initially considered justified.

The following questions need to be asked:

(i) Is the result consistent with decisions on action or inaction taken in other areas of health protection?

In other words, as was discussed in the EC 2000 Communication, "Is the action *consistent with the chosen level of protection*? It is hard to organise or logically rationalise standards of health and safety protection, which have often been developed piecemeal. However, in many societies it would be safe to say that a known risk to an individual of less than one in a million per year would be unlikely to attract regulatory action or require intervention. On the other hand, in many developed societies, an identified risk to members of the public greater than one in ten thousand per year would usually be enough to bring about regulations aimed at reducing the risk. Risks posed by EMF need to be assessed against these criteria. Precautionary interventions would probably be unacceptable if the risk, even if true, were too small.

(ii) Is the result fair and just?

A conclusion to route power lines or build additional base stations among deprived communities, even if it is more cost-effective, would probably be unacceptable on social justice grounds. There are many situations where society adopts measures for the overall benefit of the community but where the burden falls disproportionately on subsections of society. However, any such suggestions should be particularly suspect if the burden concerned involves an extra risk to health, or if the subsection of society concerned is already disadvantaged.

(iii) Is the "opportunity cost" acceptable?

Money spent on EMF reductions is money not available for spending on other health improvement measures: there is therefore an opportunity cost. The "opportunities" will, of course, depend on who is doing the assessment. Electric power and telecommunications industries have a limited horizon of opportunities that mainly revolve around their own employees and the communities they serve, whereas governments can compare EMF problems with the whole range of other health problems that affect their citizens. International organizations, for their part, will compare between developed and developing countries. If separate judgements have been reached on each health issue (including EMF) using the same criteria, there should be no opportunity cost. Nonetheless, this third reality check should still be made.

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