

Quality criteria for RF/EMF Health-Risk Assessments

Essential Criteria for Assessing Health Risks from Wireless Radiation

Response to HHS Request for Information:

“Request for Information on Electromagnetic Fields (EMFs), Radiofrequency (RF) Radiation, and Wireless Radiation Exposures”

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Background

This document responds to the Request for Information on Electromagnetic Fields (EMF), Radiofrequency (RF) Radiation, and Wireless Radiation Exposure issued by the U.S. Department of Health and Human Services. We use the terminology adopted in the Request: *“RF radiation and other forms of non-ionizing electromagnetic (EMF) exposure, will hereafter be referred to as “RF/EMF.””*

Our response addresses *“Exposure Standards and Risk Assessment”*, particularly questions 5.n, *“What scientific, technical, or regulatory changes by federal health agencies, if any, would improve the assessment, disclosure, and regulation of wireless radiation exposure?”* and 5.p, *“How, if at all, should a classification system account for exposure-related characteristics, including operating frequency, power density, specific absorption rate (SAR), electric- and magnetic-field strength, modulation and pulse characteristics, duty cycle, beamforming, simultaneous exposure to multiple frequencies, duration of exposure, distance from the source, proximity to the body, and cumulative exposure over time?”*

Our perspective is scientific, and we are members of a group giving scientific advice to Europeans for Safe Connections (an umbrella organization representing multiple European NGO’ across Europe, including National EHS patient organizations and organizations working to inform the public.).

To help *“compare regulatory approaches”*, we present criteria for evaluating the suitability of assessment methodologies rather than recommending a particular existing methodology or proposing a new one. These criteria address the methodological requirements for *“evaluating environmental factors that may affect human health”*, with the aim of supporting *“transparent science informed decision-making”* and *“practical, evidence-based recommendations for policymakers, public health stakeholder, families, schools and communities”* concerning RF/EMF health hazards, exposure safety standards, and preventive measures.

Evaluation criteria for RF/EMF health risk assessments

The following outlines the main methodological concerns addressed by our proposed criteria and their relevance to RF/EMF health-risk assessment. Appendix A explains the criteria and their scientific rationale, with particular attention to methodological choices that may lead to relevant evidence of potential health hazards being overlooked or given insufficient weight. These criteria help identifying flawed scientific studies and assessments that overlook health risks and therefore should be discarded.

Our emphasis on assessment methodology criteria, reflects the fact that the conclusions drawn from scientific evidence depend not only on the research findings themselves but also on the methodology used to evaluate the studies. Different assessment methodologies may therefore reach substantially different conclusions from the same evidence, particularly depending on how scientific uncertainty is handled and how evidentiary weight is assigned to research findings.

The criteria presented in this document specify criteria which scientific assessments should comply with and can be used to evaluate both the methodologies governing such assessments and their application in completed assessments. The criteria are not intended to be exhaustive but instead focus on issues that have been shown to introduce severe bias in the previous assessments. It is well established in the literature on risk assessment and expert advisory processes that expert bias in risk assessment is a critical determinant of the reliability of their

conclusions. Such bias mainly arises from financial or institutional conflicts of interest, and also from cognitive and professional factors. This leads to skewed judgments often due to reliance on paradigms within a specific professional environment, favoring data confirming the expert's own belief (confirmation bias), and anchoring to prior assessments. This has been described in detail for a small scientific group, highly represented in ICNIRP, WHO-EMF Group and some related scientific groups advising authorities in the EU¹. These criteria can be used to shed light on the bias in the assessments, and their methods, underlying the current exposure limits.

The purpose of the criteria is to identify assessments capable of identifying potential health hazards under realistic exposure conditions and providing a sound scientific basis for decisions concerning exposure safety standards and other preventive measures. The criteria address two levels of the assessment process: 1) handling of uncertainty and identifying potential health hazards and 2) Assigning evidentiary weight to RF/EMF research.

Part 1 — Handling uncertainty and identifying potential health hazards

Decisions about acceptable risks and protective measures involve legal, ethical, and societal considerations. Scientific hazard identification should therefore be distinguished from risk-management decisions. The scientific assessments should transparently report credible indications of potential harm and the associated uncertainties, providing a sound basis for the full risk assessment and risk-management decisions that take into account the severity of potential harm, the degree of uncertainty, the proportion of the population potentially affected, and the costs of preventive measures, among other considerations. In the context of RF/EMF, a large proportion of population is continuously exposed, something which heightens the importance of proper risk assessment and management.

In particular, such assessments should recognize and report credible indications of potential harm even when causation has not been conclusively established and should distinguish insufficient evidence of harm from evidence that potential hazards are absent.

Criteria:

1. **Potential hazards and conclusions:** Credible indications of potential harm must be identified and not disregarded due to a lack of full scientific certainty. All available evidence should be considered, and only excluded from the assessment based on scientific criteria such as serious flaws in the study design.
2. **Distinguishing lack of evidence from evidence of no hazard:** Insufficient evidence of harm must be distinguished from evidence that potential hazards are absent.
3. **Transparent reporting:** Evidentiary thresholds that reflect risk-management preferences must be explicitly identified. Risk-management preferences should not interfere with the risk-assessment.
4. **Precautionary decisions:** Credible indications of potential harm must be clearly reported, even when causation remains uncertain, to provide a scientific basis for considering preventive measures and their ethical, economic, and legal implications.

¹ www.degruyter.com/document/doi/10.1515/reveh-2022-0037/html
www.investigate-europe.eu/publications/how-much-is-safe/
www.cqlpe.ca/pdf/5G-mass-experiment-ICNIRP-cartel-Investigate-Europe.pdf
https://ehtrust.org/wp-content/uploads/lettter-hardell-roosli-to-swiss-confederation-mrs.-sommaruga-reevaluation-of-safety-standards-icnirp-5g-berenis_uvek_january-2020.pdf

Part 2 — Assigning evidentiary weight to RF/EMF research

The central purpose of these criteria is to prevent potentially important health hazards from being overlooked because relevant research findings are excluded, downgraded, or interpreted using exposure metrics that do not adequately represent the conditions being assessed.

The evidentiary weight assigned to research findings should reflect both methodological quality and the relevance of experimental exposures to the realistic conditions being assessed. This also entails considering the relevance of the included control groups. There are examples of widely cited scientific studies (e.g. PMID 22016439), with severe selection bias causing potentially higher exposure of the control group compared to the “exposure group”.

Current RF/EMF exposure limits are primarily expressed in terms of exposure magnitude, using metrics such as Specific Absorption Rate (SAR) and power density. However, RF/EMF exposures also differ in potentially biologically relevant characteristics, including modulation, pulsing, polarization, spatial distribution, and exposure duration. In scientific studies, the exposures are relevant only if the quality of the radiation is similar to that of wireless communication devices, in all the above properties. SAR only describes the rate of energy absorption per unit mass but does not characterize these other properties, some of which have been reported to have a major influence on biological responses. Consequently, studies with similar SAR values cannot automatically be assumed to investigate biologically equivalent exposures.

When assessing potential health hazards under realistic exposure conditions, particular evidentiary weight should therefore be given to studies whose exposures adequately represent the relevant characteristics of those conditions, in particular polarization and modulation as these have been reported to be of significance. Conversely, findings from studies investigating only a restricted set of exposure characteristics should not be used to exclude effects potentially associated with characteristics that were not investigated. This applies equally to findings of no effect. Furthermore, studies using short-term exposure are not suitable for evaluating the effects of long-term exposure. These considerations are especially important when evaluating studies that report no-effect of exposure.

Likewise, dose-response relationships, replication, and consistency across studies should be evaluated using exposure characteristics appropriate to the biological effects under investigation, rather than assuming that similarity in a single exposure metric establishes biological equivalence.

Criteria:

5. **Exposure relevance and evidentiary weight:** The relevance of the exposure characteristics to the target exposure scenario must be considered when assigning evidentiary weight to study findings, including findings of no effect.
6. **Interpretation of exposure metrics:** When assessing dose-response relationships, replication, and consistency across studies, the similarity of exposures must be evaluated using biologically relevant exposure characteristics, rather than assuming that similarity in a single exposure metric establishes biological equivalence.
7. **Control-group exposure contrast:** For hazard identification, exact dosimetry is not required, provided that it is reliably demonstrated that the exposed group is substantially more exposed than the control group. The exposure contrast must be sufficiently large and well characterized to support a meaningful comparison and minimize exposure misclassification.

Motivation, details and scientific references are found in Appendix A.

Recommendations to HHS

We recommend that HHS require scientific assessments, used as a basis for RF/EMF risk-management decisions, to fulfill the criteria presented in this document.

We are particularly concerned that assessments underlying the exposure limits recommended by ICNIRP and IEEE ICES do not adequately fulfill these requirements, especially regarding the handling of scientific uncertainty and the evidentiary weight assigned to studies investigating realistic RF/EMF exposures vs. unrealistic RF/EMF exposures. Similar concerns apply to assessments based on the WHO systematic reviews prepared for its RF/EMF Environmental Health Criteria monograph and to the European Commission's SCHEER opinion on RF/EMF health risks. These examples illustrate methodological concerns that may also apply to other RF/EMF assessments.

We therefore recommend that HHS evaluate all scientific assessments intended to inform RF/EMF risk-management decisions against the proposed criteria before relying on their conclusions.

About the authors of this response

Professional biography of Dr. Else K. Nordhagen

Dr. Nordhagen submits these comments in her personal capacity. She serves as a Science Advisor to Europeans for Safe Connections (esc-info.org) and is affiliated with the Norwegian NGO Foreningen for EMF Reform (emf-reform.org).

Dr. Nordhagen holds a PhD (Dr. Scient.) in Informatics/Computer Science from the University of Oslo, Norway. Her academic training includes formal logic, proof theory, and methods of scientific inference, providing a foundation for examining the methodological assumptions underlying scientific conclusions.

Before retiring, Dr. Nordhagen was a Senior Researcher at Telenor Research & Development, working on telecommunications networks, APIs, services, and mobile applications. Previously, she spent approximately ten years as a technology entrepreneur developing software services and mobile applications. Her earlier research at the Center for Industrial Research (SI/SINTEF) in Oslo included pioneering work on local area networks, client-server architectures, and related systems technologies.

Since 2017, Dr. Nordhagen has conducted research on RF/EMF and health, with particular emphasis on the methodological quality of scientific assessments and the assumptions governing the interpretation of evidence. She has authored several books on the subject and co-authored the following peer-reviewed publications:

Nordhagen EK, Flydal E. WHO to build neglect of RF-EMF exposure hazards on flawed EHC reviews? Case study demonstrates how "no hazards" conclusion is drawn from data showing hazards. *Rev Environ Health*. 2024 Jul 10;40(2):277-288. doi: 10.1515/reveh-2024-0089. PMID: 38981511.

Nordhagen EK, Flydal E. Self-referencing authorships behind the ICNIRP 2020 radiation protection guidelines. *Rev Environ Health*. 2022 Jun 27;38(3):531-546. doi: 10.1515/reveh-2022-0037. PMID: 35751553.

Professional biography of Dr. Vibeke Frøkjær Jensen

Dr. Jensen has co-authored these comments and submits in her personal capacity. She serves as a Science Advisor to Europeans for Safe Connections (esc-info.org) and is affiliated (Scientific Advisor) with the Danish Council for Safe Telecommunication (NGO founded in 2011).

Dr. Jensen holds a master's degree in veterinary science (DVM) and a Ph.D. in Clinical radiology and quantitative genetics from the University of Copenhagen, Denmark. After her Ph.D, she has held a position as scientist and senior scientist in epidemiology at the Denmark Technological University (DTU) for 20 years and contributed as scientific expert for the European Food Safety Authority, the European Medicines Agency, WHO collaborating center in Oslo and the Danish Food authority. She has published 18 peer reviewed international scientific papers as first author, and co-authored 29 peer reviewed scientific papers.

As a scientific advisor for the Danish Council for Safe Telecommunication, she has given multiple oral presentations about technical issues and biological effects of RF-EMR. In 2022-2023, she co-authored the report *Critique of SCHEER Opinion Report on Health Risks from Radiofrequency Radiation*², demonstrating the severe bias of the experts and the scientific assessment ("opinion") performed by the SCHEER ad hoc group (under the European Commission).

Professional biography of Einar Flydal

Einar Flydal is a Master of political science from the University of Oslo, Norway, and Master of Telecom Strategy and Technology Management from the Norwegian Politechnical University (NTNU), Trondheim, Norway.

He serves as a Science Advisor to Europeans for Safe Connections (esc-info.org) and is affiliated with the Norwegian NGO Foreningen for EMF Reform (emf-reform.org).

Before retiring, Flydal was a Senior Researcher at Telenor Research & Development. He has also served as a Senior Strategy Adviser in the Telenor corporate management, and as adjunct assistant professor at NTNU.

Flydal has worked in private enterprise as well as in public service with the introduction of ICT in education, internationally with the development of innovative transportation systems, as head of Norway's contribution to the development of ISO 26000 on the social responsibility of organizations, and with organizational development of oil drilling crews.

Since 2010, Flydal has studied and published extensively on health and environmental effects of man-made EMFs. He has authored numerous posts and reviews for a larger public, translated scientific papers and books on the topic, written and co-edited books, and co-authored the following peer-reviewed publications:

Nordhagen EK, Flydal E. WHO to build neglect of RF-EMF exposure hazards on flawed EHC reviews? Case study demonstrates how "no hazards" conclusion is drawn from data showing hazards. *Rev Environ Health*. 2024 Jul 10;40(2):277-288. doi: 10.1515/reveh-2024-0089. PMID: 38981511.

Nordhagen EK, Flydal E. Self-referencing authorships behind the ICNIRP 2020 radiation protection guidelines. *Rev Environ Health*. 2022 Jun 27;38(3):531-546. doi: 10.1515/reveh-2022-0037. PMID: 35751553.

² www.stralskyddsstiftelsen.se/wp-content/uploads/2023/10/SCHEER-report_oct2_2023_final.pdf.

Professional biography of Cornelia Waldmann-Selsam

Cornelia Waldmann-Selsam is an MD from Bamberg in Germany. She serves as a Science Advisor to Europeans for Safe Connections (esc-info.org).

Dr. Waldmann-Selsam was the Co-initiator of the Bamberg Appeal 2004, in which 130 medical doctors warned against expanding mobile phone networks. After the appeal was published many residents living near mobile phone base stations contacted the initiative for help with health issues. Between 2004 and 2007 Waldmann-Selsam visited therefore 1600 residents living nearby mobile phone base stations, documented their symptoms and took RF radiation measurements.

In 2006 Presentation of case reports at the expert discussion “Health Effects of Electromagnetic Fields of Wireless Communication Technologies - Case reports” at the Federal Office for Radiation Protection. Nevertheless, the Federal Office for Radiation Protection claimed that people cannot become ill from base station radiation below current exposure limits and that people develop symptoms out of concern and fear.

Around the same time when symptoms appeared often damage to trees started also. Of particular concern was the unilateral crown damage that began on the side of the tree facing the mobile phone base station.

Between 2005 and 2016 Waldmann-Selsam documented the visible tree damage in the vicinity of over 1,500 mobile phone base stations

Publications

Waldmann-Selsam C (2005). „Dokumentierte Gesundheitsschäden unter dem Einfluss hochfrequenter elektromagnetischer Felder“ mit 26 Fallbeispielen, April 2005

Waldmann-Selsam C (2009, 2019). Case reports in umwelt medizin gesellschaft (3/2009, 2/2019)

Waldmann-Selsam C, Puente A, Breunig H, Balmori A (2016). Radiofrequency radiation injures trees around mobile phone base stations. *Science of the Total Environment*, 572, 554–569. <https://doi.org/10.1016/j.scitotenv.2016.08.045>

Aschermann C, Waldmann-Selsam C (2017) Elektrosensibel – Strahlenflüchtlinge in einer funkvernetzten Gesellschaft, shaker

Waldmann-Selsam C (2025). Tree Damage Caused by Radiofrequency Radiation Key Observations from 2005 to 2025 in Germany

Professional biography of Dr. Fiorella Belpoggi

Dott.ssa Fiorella Belpoggi was Scientific Director and Scientific Advisor at the Ramazzini Institute in Bologna until 2023. From 1981 to 2001, he collaborated closely with Professor Cesare Maltoni, an internationally renowned oncologist, then Director of the same Institute. Expert in the study of agents that can determine tumors and other environmental pathologies, such as plastic monomers, asbestos, fuels and gasoline additives, pesticides, in particular endocrine disruptors, ionizing radiation and low-frequency electromagnetic fields (ELFEMF) and radiofrequency electromagnetic fields (RF-EMF), heavy metals, etc. Particular attention was paid to the topic of nutrition and that of the risks associated with simultaneous exposures even to small doses of chemicals or physical agents, especially during embryonic and fetal life, as well as in childhood. She also worked on evaluating the effectiveness of pharmaceutical and herbal drugs and active ingredients in combating the onset and development of neoplasms.

She is a member of the International Academy of Toxicological Pathology (IATP), the American Society of Toxicological Pathology (STP) and the European Society (ESTP), the New York Academy of Sciences, and the Collegium Ramazzini, an International Academy of over 180 independent expert members in the field of occupational and environmental diseases, representing 36 countries worldwide (www.ramazzini.org). He is an active member of the Scientific Committee of the International Society of Doctors for Environment- Italy; Honorary President of the Bolognese Apennine Biodistrict, member of the "Placido Rizzotto" Observatory for the Health of Agricultural Workers; he is a member of ICBE-EMF (The International Commission on the Biological Effects of Electromagnetic Fields) dedicated to enhancing the protection of humans and other species from the harmful effects of non-ionizing electromagnetic fields ESC, Europeans for Safe Connections, an alliance of European organizations that strikes to reduce the impact of modern communications and electricity use on health and the environment. For two decades, she was the point of contact for the Ramazzini Institute's relations with the important American research institution, the National Institute of Environmental Health Sciences (NIEHS); she was called to the European Commission several times to report on relevant health and environmental issues. She was part of the IARC Working Groups for the drafting of Monographs 120 on Benzene, 125 and 130 on Certain Industrial Compounds, and of the working group that established the IARC priorities 2020-2024. She was invited to join the EU SCHEER RF-EMF Working Group and the EFSA Working Group for the evaluation of the request for re-authorization of Glyphosate in Europe. She was commissioned by the Panel for the Future of Science and Technology (STOA) European Parliament to prepare the Health impact of 5G report for the European Parliament, published in June 2021. She has participated as a speaker at hundreds of public events in Italy and abroad on topics of interest. She authored about 200 peer reviewed papers.

<https://www.researchgate.net/profile/Fiorella-Belpoggi>

<https://unibo.academia.edu/FiorellaBelpoggi>

Appendix A: Scientific and methodological rationale for the proposed criteria

This appendix provides the legal, scientific and methodological rationale for the criteria presented in our comment.

Why a preventive approach is appropriate when assessing RF/EMF health risks

RF/EMF exposure should be treated in the same manner as other potential detrimental exposures and therefore adhere to a preventive approach. U.S. law contains important examples of courts ordering companies to follow a preventive approach. In *Ethyl Corp. v. EPA* (1976)¹, the D.C. Circuit held that environmental regulation does not need to wait until actual harm has been conclusively demonstrated. The court recognized that agencies often must make decisions in the presence of scientific uncertainty and stated that "*we will not demand rigorous step-by-step proof of cause and effect.*" The court further recognized that risk assessments may rely on incomplete but credible evidence, including observed trends, theoretical considerations, and suspected relationships that have not yet been fully established.

Although *Ethyl Corp.* interpreted the Clean Air Act rather than the Communications Act, it illustrates an important principle of public-health regulation: lack of absolute proof of harm is not the same as lack of health risk.

This principle is relevant in assessing health risks from RF/EMF and therefore a regulatory approach should follow a preventive approach. This means that first a risk assessment should be done which not only considers the strength and consistency of the evidence, but also whether the totality of the available evidence provides credible indications of health risks. If the assessment concludes that there are credible indications of health risks, risk management should follow, including an assessment of potential severity, prevalence, reversibility, and societal consequences of the possible harm identified by the risk assessment. The conclusions should then be used for justifying protective measures, advice to the public, recommendations for further investigation, adjustment of exposure limits and/or safety margins.

In a preventive approach, it is recognized that the consequences of failing to recognize a genuine hazard may be substantial when exposure is widespread and involuntary, as is the case in realistic RF/EMF deployment scenarios in the United States.

A given assessment method is meaningful only in relation to the purpose of the assessment. Thus, the method's evidentiary threshold and quality criteria must reflect the purpose of the assessment. In a protective approach, evidentiary weight must be given to credible indications of harm and to the consequences of failing to identify a real hazard. Waiting for complete scientific certainty may leave large populations exposed for many years before protective measures are considered. Quality criteria must give particular evidentiary weight to studies investigating realistic exposure scenarios.

This document presents a non-exhaustive list of general requirements for a methodology for assessing health risks under realistic exposure scenarios. It addresses requirements related to

¹ *Ethyl Corp. v. Environmental Protection Agency*, 541 F.2d 1 (D.C. Cir. 1976) (en banc), cert. denied, 426 U.S. 941 (1976).

evidentiary threshold and evidentiary weight. The evidentiary threshold determines the degree of evidence required before a potential health hazard is recognized, and thereby how uncertainty is handled. Evidentiary weight concerns how strongly individual studies contribute to the overall assessment, taking into account their relevance, quality, and other characteristics. In this document, particular attention is given to the relevance of studies to realistic RF/EMF exposure scenarios.

This distinction is important because an assessment can fail to recognize credible indications of a potential hazard for two different reasons. First, it may examine relevant evidence but apply such a demanding standard of proof that the evidence is considered insufficient to establish a hazard. Second, it may give little weight to relevant studies because its inclusion, exclusion, or quality criteria favor other kinds of studies. These mechanisms may also reinforce one another. Distinguishing between them makes it possible to identify both problems independently, which is particularly useful when comparing assessments and assessment methodologies.

An illustration of the importance of assessment methodology is the difference in conclusions of some systematic reviews substantially overlapping primary studies. These reviews address RF/EMF exposure and cancer in laboratory animals. Pinto et al. (2023², 2024³) and Mevissen et al. (2025⁴) examined substantially overlapping primary studies but reached markedly different conclusions: Pinto et al. considered the evidence for carcinogenic effects uncertain or insufficient, whereas Mevissen et al. concluded that there was high-certainty evidence of increased risks of certain cancers. This illustrates the importance of examining how methodological choices may influence the conclusions drawn from essentially the same scientific evidence.

Part 1: Requirements for evidentiary threshold

1.1 The handling of uncertainty must focus on identifying health hazards

To evaluate whether exposure to RF/EMF poses a risk to public health, the evidentiary threshold must be suited to handling uncertainty in an appropriate way. An assessment method must therefore give appropriate weight to credible indications of harm and to the consequences of failing to identify a real hazard.

The scientific assessment should explicitly report credible indications of potential hazards, the strength of the supporting evidence, and the remaining uncertainties, including effects for which a causal relationship has not been established. These uncertainties should not be implicitly resolved through methodological requirements for conclusive proof before a possible hazard is acknowledged. This provides a transparent basis for subsequent risk-management decisions.

² Pinto, R.; Ardoino, L.; Villani, P.; Marino, C. In Vivo Studies on Radiofrequency (100 kHz–300 GHz) Electromagnetic Field Exposure and Cancer: A Systematic Review. *Int. J. Environ. Res. Public Health* 2023, 20, 2071. <https://doi.org/10.3390/ijerph20032071>

³ Pinto, R.; Ardoino, L.; Giardullo, P.; Villani, P.; Marino, C. A Systematic Review on the In Vivo Studies on Radiofrequency (100 kHz–300 GHz) Electromagnetic Field Exposure and Co-Carcinogenesis. *Int. J. Environ. Res. Public Health* 2024, 21, 1020. <https://doi.org/10.3390/ijerph21081020>

⁴ Mevissen M, Lerchl A, Burridge P, et al. Effects of radiofrequency electromagnetic field exposure on cancer in laboratory animal studies: a systematic review. *Environ Int.* 2024;181:108248. <https://doi.org/10.1016/j.envint.2025.109482>

Established approaches to health hazard identification include Bradford Hill's considerations⁵ for causal inference and the IARC Preamble⁶, which provides a structured framework for evaluating evidence of carcinogenic hazards. Such approaches assess evidence from multiple scientific domains and allow potential hazards to be recognized without requiring conclusive proof of causation. In this context, the triangulation principle should be applied, giving higher weight to different lines of research supporting the same endpoint /effect⁷. Replication is important but may also be misleading in case the same errors in the study design are replicated.

These approaches have been applied to RF/EMF. IARC classified RF electromagnetic fields as possibly carcinogenic to humans (Group 2B), while the European Parliament's STOA report⁸, applying an IARC-based classification approach, identified stronger evidence for carcinogenic and reproductive/developmental hazards. Other assessments, including those from EUROPAEM⁹ and The BioInitiative Group¹⁰, and the scientific review published by ICBE-EMF¹¹, have also identified potential adverse effects below existing exposure limits.

Evaluation criteria:

1 Potential hazards identification: Credible indications of potential harm must be identified and not disregarded due to a lack of full scientific certainty.

2 Distinguishing lack of evidence from evidence of no hazard: Insufficient evidence of harm must be distinguished from evidence that potential hazards are absent.

1.2. Setting evidentiary thresholds may entail risk-management decisions

There will always be some degree of uncertainty about how probable a health risk is, when based on empiric evidence. How this uncertainty should be handled is not a purely scientific question, but also a question of risk management. Risk management has ethical and legal implications and must therefore include an assessment of the potential severity, prevalence, reversibility, and societal consequences of the possible harm identified by the scientific assessment. The outcome should inform decisions concerning protective measures, advice to

⁵ Hill AB. The environment and disease: association or causation? *Proc R Soc Med.* 1965;58(5):295–300. https://en.wikipedia.org/wiki/Bradford_Hill_criteria

⁶ International Agency for Research on Cancer (IARC). Preamble to the IARC Monographs on the identification of carcinogenic hazards to humans [Internet]. Lyon: IARC; 2019 [cited 2026 Mar 10]. Available from: <https://monographs.iarc.who.int/wp-content/uploads/2019/07/Preamble-2019.pdf>
<https://monographs.iarc.who.int/iarc-monographs-preamble-preamble-to-the-iarc-monographs/>

⁷ <https://www.nature.com/articles/d41586-018-01023-3>

⁸ Health impact of 5G – Current state of knowledge of 5G-related carcinogenic and reproductive/developmental hazards as they emerge from epidemiological studies and in vivo experimental studies, European Parliamentary Research Service, Scientific Foresight Unit (STOA), PE 690.012 – July 2021, [https://www.europarl.europa.eu/RegData/etudes/STUD/2021/690012/EPRS_STU\(2021\)690012_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2021/690012/EPRS_STU(2021)690012_EN.pdf)

⁹ Belyaev I, Dean A, Eger H, Hubmann G, Jandrisovits R, Kern M, Kundi M, Moshhammer H, Lercher P, Müller K, Oberfeld G, Ohnsorge P, Pelzmann P, Scheingraber C, Thill R. 2016 EUROPAEM EMF Guideline 2016 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. *Rev Environ Health*, vol. 31, no. 3, 2016, pp. 363-397 <https://doi.org/10.1515/revch-2016-0011>

¹⁰ Bioinitiative Working Group, David Carpenter and Cindy Sage (eds). 2012 Bioinitiative 2012: A rationale for biologically-based exposure standards for electromagnetic radiation. <http://www.bioinitiative.org>

¹¹ International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF). Scientific evidence invalidates health assumptions underlying the FCC and ICNIRP exposure limit determinations for radiofrequency radiation: implications for 5G. *Environ Health* 21, 92 (2022). <https://doi.org/10.1186/s12940-022-00900-9>

the public, recommendations for further investigation, adjustments of exposure limits, and/or safety margins.

The choice of evidentiary threshold determines how much scientific uncertainty is accepted for a potential hazard to be acknowledged. Such thresholds may implicitly reflect risk-management preferences concerning the consequences of overlooking a real hazard versus incorrectly identifying one.¹² These preferences involve policy choices and should therefore be explicitly identified and made transparent.

A key question is whether a high evidentiary threshold effectively shifts responsibility for documenting harmful effects from the authorities to the people who experience them. This raises a question about whether such a shift in the burden of proof is ethically acceptable.

It is also important that the assessment describes the criteria used to assign evidentiary weight to research results, as these directly influence which potential health hazards are adequately assessed and which may receive insufficient consideration. This is addressed in Part 2.

Evaluation criteria:

3. Transparent reporting: Evidentiary thresholds that reflect risk-management preferences must be explicitly identified.

1.3. Scientific assessments must provide a basis for precautionary decisions

From a public-health perspective, particular attention should be given to potential hazards involving serious or irreversible harm. In such cases, a false negative (failing to recognize a genuine hazard) can have substantial consequences for public health. Therefore, a precautionary approach may justify a lower evidentiary threshold for considering preventive measures.

When assessing potential health hazards, two types of errors are possible:

- False negative (FN): Failing to recognize a health hazard that actually exists.
- False positive (FP): Concluding that a health hazard exists when it does not.

The consequences of these errors depend on the purpose of the assessment and the decisions based on its conclusions. In public-health assessments, false negatives may have particularly serious consequences when exposure is widespread, involuntary, or associated with potentially irreversible harm, as may be the case under realistic RF/EMF exposure scenarios.

The choice of how to balance these errors is not value-neutral. It can be formalized using decision theory. The Bayes decision rule¹³ provides a framework in which the probabilities and consequences of different outcomes determine the decision that minimizes expected loss.

In this framework, expected loss can be illustrated by the following simplified expression based on Bayesian decision theory:

¹² Late lessons from early warnings: Science, precaution, innovation. EEA Report No 1/2013. The European Environmental Agency. ISSN 1725-9177 www.eea.europa.eu/en/analysis/publications/late-lessons-2

¹³ Yuille AL. Lecture 2: Bayes Decision Theory. Johns Hopkins University; 2014. Available from: <https://www.cs.jhu.edu/~ayuille/>

$$\text{Expected loss} = P(\text{FP}) \times \text{Cost}(\text{FP}) + P(\text{FN}) \times \text{Cost}(\text{FN})$$

where $P(\text{FP})$ and $P(\text{FN})$ represent the probabilities of false-positive and false-negative decisions, respectively, and the cost terms represent their consequences.

When the expected consequences of overlooking a genuine hazard are substantially greater than those of introducing unnecessary protective measures, minimizing expected loss favors a precautionary decision. This may justify preventive measures even when the scientific evidence is insufficient to establish a causal relationship with high confidence, but where the probability of a detrimental health effect cannot be dismissed.

Consequently, the more people potentially affected by a health hazard, the lower the probability of harm needed to justify preventive measures, all else being equal. If the preventive measures are simple and inexpensive, such as advising people to keep some distance from wireless devices, precautionary action may be even more justified.

In summary, the greater the cost of overlooking a genuine hazard relative to the cost of unnecessary protective measures, the lower the probability of harm required to justify precautionary action.

Thus, precaution can be justified not only by ethical considerations, but also by rational decision-making that accounts for the probabilities and consequences of errors. The relative costs of false negatives and false positives, however, involve ethical, economic, and societal judgments that should be transparent and subject to public-policy decisions rather than being implicitly determined by scientific assessment methods.

Different stakeholders may assign different costs to false positives and false negatives. For example, economic or technological interests may favor avoiding false positives and the resulting costs of unnecessary restrictions, while public-health protection may place greater weight on avoiding false negatives and their potentially serious consequences. Such differences in priorities can substantially influence the evidentiary threshold considered acceptable. These priorities must therefore be made explicit so that they can be evaluated against applicable legal and ethical obligations, rather than remaining implicitly embedded in the criteria used to assess scientific evidence.

Evaluation criteria:

4. Precautionary decisions: Credible indications of potential harm should be clearly reported, even when causation remains uncertain, to provide a scientific basis for considering preventive measures and their ethical, economic, and legal implications.

Part 2: Assigning evidentiary weight to RF/EMF research results

Inclusion, exclusion, and Risk of Bias (RoB) criteria should ensure that studies are evaluated according to their relevance and methodological quality. Relevant studies should not be excluded or downgraded because they fail to meet requirements that are not pertinent to the biological effects under investigation. Particular evidentiary weight should be given to studies investigating realistic exposure scenarios.

RF/EMF exposures from wireless communication systems differ in several potentially biologically relevant characteristics beyond carrier frequency and exposure intensity. These

differences must be considered when evaluating the relevance of experimental studies and interpreting their findings.

The following evaluation criteria address essential methodological requirements for assessing evidence of potential health effects from RF/EMF exposure. These criteria are intended for evaluating assessment methodologies and their application in completed assessments, including systematic reviews, rather than serving as a comprehensive checklist for individual studies. Some of the criteria relate to individual studies, but then as part of the hazard identification process in risk assessment. The criteria are not exhaustive.

2.1 Exposure characterization must reflect biologically relevant properties.

RF/EMF exposures from wireless communication systems are characterized not only by carrier frequency and intensity, but also by polarization, modulation, pulsing, and other temporal and spatial properties. These characteristics vary between technologies, operating conditions, and exposure scenarios.

Experimental studies have reported that RF/EMF characteristics other than Specific Absorption Rate (SAR) can influence biological responses, including in research investigating adverse effects^{14,15,16,17} and therapeutic applications¹⁸. SAR characterizes the rate of RF energy absorption per unit mass but does not capture important exposure characteristics potentially relevant to biological responses. These studies report that polarization and modulation are more important properties than SAR, and thus studies with similar SAR values cannot automatically be assumed to investigate biologically equivalent exposures.

Regulatory bodies basing their assessments and advice on SAR alone, argue that there is no evidence that continuous (e.g., sinusoidal) and discontinuous (e.g., pulsed) EMFs result in different biological effects and often used references are the two papers (Kowalczyk et al. 2010¹⁹; Juutilainen et al. 2011²⁰). These have an engineering view of passive body tissue assuming they only will react to modulated signals if they have diode-like elements which can physically rectify radio waves into low-frequency currents. The modern view of biology sees the body as a dynamic, living electrical system with its own electromagnetic signaling systems. In addition, Juutilainen focused almost exclusively on blunt, macroscopic health

¹⁴ Belyaev, I., 2015. Biophysical mechanisms for nonthermal microwave effects. In: Markov M.S. (Ed), *Electromagnetic Fields in Biology and Medicine*, CRC Press, New York, pp 49-67.

https://ec.europa.eu/health/scientific_committees/scheer/docs/emf2022/2015_Belyaev.pdf

¹⁵ Panagopoulos DJ, Yakymenko I, De Iuliis GN, Chrousos GP (2025). A comprehensive mechanism of biological and health effects of anthropogenic extremely low frequency and wireless communication electromagnetic fields. *Frontiers of Public Health*, Jun 4; 13:1-23. <https://doi.org/10.3389/fpubh.2025.1585441>

¹⁶ Lai, H., & Levitt, B. B. (2022). The roles of intensity, exposure duration, and modulation on the biological effects of radiofrequency radiation and exposure guidelines. *Electromagnetic Biology and Medicine*, 41(2), 230–255. <https://doi.org/10.1080/15368378.2022.2065683>

¹⁷ *Recent Advances in Bioelectromagnetism and Subtle Energies Implications for Health and Disease*, ed. Jan Martel, Academic Press 2026, ISBN 0443330182

¹⁸ Libhoff 2015, “Electromagnetic Therapy: A Primer” <https://www.researchgate.net/publication/303911386>

¹⁹ Kowalczyk C, Yarwood G, Blackwell R, Priestner M, Sienkiewicz Z, Bouffler S, Ahmed I, Abd-Alhameed R, Excell P, Hodzic V, Davis C, Gammon R, Balzano Q. Absence of nonlinear responses in cells and tissues exposed to RF energy at mobile phone frequencies using a doubly resonant cavity. *Bioelectromagnetics* 31(7):556–565; 2010.

²⁰ Juutilainen J, Höytö, Kumlin T, Naarala J. Review of possible modulation-dependent biological effects of radiofrequency fields, *Bioelectromagnetics* 32(7):511–34; 2011.

endpoints like cancer and DNA breaks, dismissing reported subtle cellular variations as experimental noise.

Both papers, and thus ICNIRP, overlook how the repetitive, coherent switching of modern pulsed signals (like 5G TDD) can physically jolt voltage-gated ion channels, alter radical-pair chemistry, and induce downstream oxidative stress or calcium signaling leaks—functional biochemical disruptions that occur long before a tumor develops and that smooth, continuous waves do not replicate at identical average power levels. Also, it is often argued that only ionizing radiation can cause biological harm. It is, however, overlooked, that the majority of the DNA damage resulting from ionizing radiation is an indirect effect through the formation of reactive oxygen species (ROS) and oxidative stress²¹. Modulated, polarized RF-EMF exposure has been linked to the formation of ROS oxidative stress in more than a hundred studies.

The relevance of individual exposure characteristics depends on the target exposure scenario and biological endpoint under investigation. Assessment methodologies should therefore consider how adequately experimental exposures are characterized and how well they represent the conditions being assessed, such as exposures from wireless devices and base stations under realistic operating conditions.

Manmade RF- EMF from communication technologies is polarized and heavily modulated. Therefore, all studies using exposure that is not modulated and polarized similarly to that from communication technologies, should be excluded in the assessment of scientific evidence as the exposure is irrelevant.

A study investigating only a restricted set of exposure characteristics should not be used to exclude effects potentially associated with characteristics that were not investigated.

Definition 4.A: For the purpose of this assessment, exposure characteristics include carrier frequency and bandwidth; modulation, pulsing, and other temporal variations; field strength and power density, polarization and spatial field distribution; source distance, orientation, and proximity to the exposed subject; and exposure duration and intermittency.

These characteristics are described in more detail in the following table:

²¹ Yahamoto et al., 2010. Pretreatment with Ascorbic Acid Prevents Lethal Gastrointestinal Syndrome in Mice Receiving a Massive Amount of Radiation. *J. Radiat. Res.*, 51, 145–156. <https://pubmed.ncbi.nlm.nih.gov/19959877/>. See also <https://www.mdpi.com/2076-3921/14/9/1085> and <https://acamedicine.org/article/10-4328-acam-22411/>

Property	What should be characterized	Why it matters for comparison
1. Frequency characteristics	Carrier frequency or frequency bands, bandwidth, and simultaneous frequencies	Different technologies use different frequency ranges; frequency also affects propagation and absorption. Also, the biological effect may vary depending on the frequency.
2. Temporal characteristics	Modulation, pulsing, pulse repetition, duty cycle, pulse duration, rise/fall times, peak-to-average ratio and variations over time	Two exposures with similar average intensity may have very different temporal structures
3. Exposure magnitude	Electric and magnetic field strengths, power density, SAR where applicable, peak and average values	Establishes whether exposure levels are comparable to the target scenario
4. Spatial and field characteristics	Polarization, spatial coherence where relevant, near-field/far-field conditions, field distribution and beamforming	Describes how fields are distributed and interact with the exposed subject
5. Exposure geometry	Distance, orientation, source position, body proximity, and exposed anatomical regions	Determines which tissues are exposed and how exposure varies with position
6. Exposure duration and variability	Exposure duration, intermittency, cumulative exposure, operating modes and changes over time	Distinguishes short laboratory exposures from repeated or prolonged real-world exposure

The potential importance of temporal and spatial exposure characteristics is also supported by proposed biophysical interaction mechanisms involving nonlinear biological systems, cellular membranes and other molecular structures¹²⁻¹⁵. Although the applicability of individual mechanisms remains under investigation, these considerations provide additional reasons not to assume that SAR alone adequately characterizes exposure for all biological endpoints.

In hazard identification, it is pertinent that the exposure scenario is relevant. The exposure needs to be relevant in terms of modulation and polarization, and the duration and intensity needs to be sufficient/comparable to the target scenario. In hazard identification, strict dosimetry is not necessary, as other metrics can be applied to ensure that the exposure is relevant. Also, it must be documented that the control group exposure is sufficiently low.

Evaluation criteria:

5. Exposure relevance and evidentiary weight: The relevance of the exposure characteristics to the target exposure scenario must be considered when assigning evidentiary weight to study findings, including findings of no effect.

6. Control-group exposure contrast: In hazard identification, exact dosimetry is not required, provided that it is reliably demonstrated that the exposed group is substantially more exposed than the control group. The exposure contrast must be sufficiently large and well characterized to support a meaningful comparison and minimize exposure misclassification.

2.2 Dose-response, replication and consistency must be evaluated using appropriate exposure metrics

When evaluating dose-response relationships, replication, or consistency across studies, the exposure metrics used must be appropriate for the biological effects under investigation. Traditionally, dosimetry of the relevant agents are needed in order to quantify risk. However, in realistic scenarios as to RF/EMR such dose-response mapping of the relevant agents and their properties is extremely complex, if at all feasible and only haphazardly related to SAR: Different RF/EMF exposures may have similar values for a particular exposure metric, such as SAR, field strength, or power density, while differing in other characteristics potentially relevant to biological responses, such as modulation, pulsing, or polarization. Therefore, similarity in a single exposure metric should not automatically be interpreted as biological equivalence.

Evaluation criteria

7. Interpretation of exposure metrics: When assessing dose-response relationships, replication, and consistency across studies, the similarity of exposures must be evaluated using biologically relevant exposure characteristics, rather than assuming that similarity in a single exposure metric establishes biological equivalence.

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