Review

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Self-referencing authorships behind the ICNIRP 2020 radiation protection guidelines

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Abstract: In March 2020, ICNIRP (the International Commission for Non-Ionizing Radiation Protection) published a set of guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz). ICNIRP claims this publication's view on EMF and health, a view usually termed "the thermal-only paradigm", is consistent with current scientific understanding. We investigated the literature referenced in ICNIRP 2020 to assess if the variation in authors and research groups behind it meets the fundamental requirement of constituting a broad scientific base and thus a view consistent with current scientific understanding, a requirement that such an important set of guidelines is expected to satisfy. To assess if this requirement has been met, we investigated the span of authors and research groups of the referenced literature of the ICNIRP 2020 Guidelines and annexes. Our analysis shows that ICNIRP 2020 itself, and in practice all its referenced supporting literature stem from a network of co-authors with just 17 researchers at its core, most of them affiliated with ICNIRP and/or the IEEE, and some of them being ICNIRP 2020 authors themselves. Moreover, literature reviews presented by ICNIRP 2020 as being from independent committees, are in fact products of this same informal network of collaborating authors, all committees having ICNIRP 2020 authors as members. This shows that the ICNIRP 2020 Guidelines fail to meet fundamental scientific quality requirements and are therefore not suited as the basis on which to set RF EMF exposure limits for the protection of human health. With its thermal-only view, ICNIRP contrasts with the majority of research findings, and would therefore need a particularly solid scientific foundation. Our analysis demonstrates the contrary to be the case. Hence, the ICNIRP 2020 Guidelines cannot offer a basis for good governance.

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Introduction

In March 2020, ICNIRP (the International Commission for Non-Ionizing Radiation Protection, a small, privately constituted group, with non-transparent, self-appointed membership [1]), published a new set of guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz) [2] with two annexes (in their entirety, hereinafter referred to as "ICNIRP 2020", and the mentioned radiation as "RF EMF"). The guidelines' authors claim that safe exposure levels for RF EMF may be set according to thermal levels, as – purportedly – no health hazards from RF exposure exist below such levels, and that this view is "*consistent with current scientific understanding*" [2 p. 484]. This view on health effects is below termed "the thermal-only paradigm". We investigated the literature referenced in ICNIRP 2020 to assess if the variation in authors and research groups behind it meets the fundamental requirement of constituting a broad scientific base, and thus is consistent with current scientific understanding, a requirement that such an important set of guidelines is expected to satisfy.

Such a check is particularly important as ICNIRP members are found to have conflicts of interest, as pointed out by e.g., [3]: "*the Ethical Board at the Karolinska Institute in Stockholm, Sweden concluded already in 2008 that being a member of ICNIRP may be a conflict of interest that should be stated officially whenever a member from ICNIRP makes opinions on health risks from EMF (Karolinska Institute diary number: 3753-2008-609)*". An EU report [4] concluded in June 2020 that "*for really independent scientific advice we cannot rely on ICNIRP*". An implication is that any referenced literature co-authored by an ICNIRP member should not be considered independent of ICNIRP's thermal-only view and the document's conclusions cannot *per se* be relied upon as being scientifically sound. Therefore, we were interested in checking the degree of independence from ICNIRP of the literature used in ICNIRP 2020 to

underpin its thermal-only view. ICNIRP members found as authors of referenced literature would imply an obligatory adherence to the thermal-only paradigm, as an ICNIRP member cannot be expected to support the opposing view when co-authoring with others.

As is apparent from the debate on this issue, a majority of peer-reviewed papers support the opposing view, i.e., that sub-thermal RF EMFs have health effects [5]. Several athermal mechanisms have been identified [6–10] and accepted as evidenced, if not proven.

Two questions are therefore raised: When negating athermal health hazards, how does ICNIRP underpin the claim that the thermal-only view is consistent with current scientific understanding? Could it be that the referenced literature used to underpin ICNIRP2020 *is not* representative of the corpus of established knowledge, but, contrary to ICNIRP 2020 claims, quite biased? Answering the latter question was the motivation for the assessment presented here. This general question has been refined and reformulated into the following more detailed questions:

(1) Who are the authors behind the literature referenced in ICNIRP 2020?
(2) ICNIRP 2020 bases its conclusions on several *literature reviews* which are presented as if authored by others than ICNIRP and its affiliates. How independent are these reviews?
(3) How independent are the referenced peer reviewed *papers* used to underpin ICNIRP 2020?
(4) As *first authors* seem to vary markedly, a first impression of ICNIRP 2020 is that it refers to a rich variety of researchers and research groups. Is this impression correct?
(5) How are peer reviewed papers (and reviews) which do not support ICNIRP's thermal-only view handled?

This paper presents six patterns emerging from our analysis of the authors behind the referenced literature in ICNIRP 2020. The patterns describe features from which we can evaluate the referenced literatures' representativity and independence, and the way the thermal-only view, on which ICNIRP 2020 is based, is underpinned.

Method used

First, we identified *all authors of all literature referenced in ICNIRP 2020* who are up to 2020 current or former members of the ICNIRP Commission or the ICNIRP Scientific Expert Group. In the following we term these authors "*the ICNIRP affiliates*".

Second, we constructed the complete *network of co-authorship relations within the referenced literature* originating from these ICNIRP affiliates. This co-authorship network is presented in Pattern 1 below. For network visualizations, we used simple drawings and a standard software for network mapping (Gephi graph tool).

Third, we identified the *members of the committees behind the seven major literature reviews* referenced in ICNIRP 2020 to underpin their claims related to RF EMF and health. These reviews are [11, 12], and the reviews presented in ICNIRP 2020 as (SSM 2015, 2016, 2018) and (HCN2014, 2016). These latter reviews are not included in our list of references.

We also identified *members of the committee authoring ICNIRP 2020 and the six ICNIRP publications referenced* in ICNIRP 2020.

We then identified *persons who are members of more than one of these committees*, to discover the degree to which there were overlapping memberships, hence lack of independence between the committees and ICNIRP. The results are presented in Pattern 2 below. The network identified in Pattern 1 is further detailed in Patterns 3 and 4:

In Pattern 3 we identify all *peer reviewed papers from the co-authorship network* identified in Pattern 1 for the same purpose of tracing possible overlap and lack of independence.

In Pattern 4 we identify some *key authors who alone or together are co-authors of all identified papers* from Pattern 3 and *all committee reports* in Pattern 2. The number of key authors indicates the degree of authorship concentration and links to ICNIRP.

Pattern 5 identifies *first authors of the peer reviewed papers* and *their positions in the ICNIRP co-authorship network (Pattern 1)*. This pattern reveals the centrality of first authors.

Pattern 6, the last pattern, depicts how ICNIRP 2020 handles the referenced *peer reviewed papers not authored by the ICNIRP co-authorship network*.

Taken together, these patterns answer the questions we raised in the introduction.

Several of the presented patterns emerge only after detailed analyses. To make the content more accessible to the reader, we present our findings and conclusions before going into more detail.

The enumerations of authors and literature have been done manually with the help of simple search functions and spread sheets. Therefore, there might be minor summation errors. There may also be co-authorship relations between what seems here to be independent authors and ICNIRP affiliates. Such relations might be

revealed by wider searches outside the ICNIRP 2020 referenced literature. One such co-authorship relation identified is discussed below.

However, the six patterns emerging from our analysis are so distinct that minor summation errors and co-authorship relations not found would not change the overall conclusions in any significant way.

All in all, ICNIRP 2020 has 158 unique references. Not all have been authored by the ICNIRP co-authorship network found in Pattern 1. We found that the network co-authored 78 of the referenced peer reviewed papers, seven of the literature reviews, and six ICNIRP publications, in total 91 documents. In addition to these 91 documents, there are 67 references to other documents.

Of these 67 documents, only 15 are peer reviewed papers on RF EMF and health. The remaining 52 are documents with no direct relation to this topic. We termed these 52 "technical documents", as they address topics such as WHO's definition of "health" and other general terms used (three documents), thermal regulation (20 documents), contact currents and pain (five documents), technical documentation (three documents) and SAR-modelling and calculations (21 documents). We excluded these technical documents from further analyses (see Figure 1).

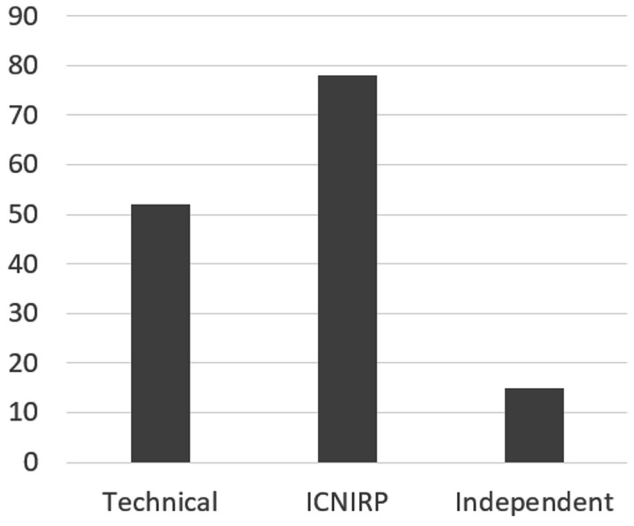

Figure 1: The number of different kinds of documents referenced in ICNIRP 2020.
The documents are sorted as follows: technical documents (52), ICNIRP affiliated authorships (91), and independent authorships (15). "Technical" refers to topics not directly related to RF EMF exposure and health end points. "ICNIRP" refers to ICNIRP affiliated authorships, and includes peer reviewed papers, literature reviews and ICNIRP reports authored by the ICNIRP co-authorship network identified in Pattern 1. "Independent" refers to papers with no authors from the ICNIRP co-authorship network.

Pattern 1: ICNIRP affiliates and ICNIRP 2020 authors are heavily involved in literature referenced in ICNIRP 2020 to underpin it

We mapped the complete network of co-authorship relations originating from the ICNIRP affiliates, using the author lists of the peer reviewed papers referenced in ICNIRP 2020, as well as the members of committees behind the literature reviews. Hereinafter this network is referred to as "the ICNIRP co-authorship network".

The network visualization revealed that some persons were more central than others, forming nodes with many co-authorship relations. See Figure 2 where the nodes represent persons, and co-authorships are represented as "edges", i.e., connecting lines. The more co-authorship relations, the larger the node, i.e., the more central is the author.

In Figure 2 we see that the following names appear as central co-authors of the referenced documents used to underpin ICNIRP 2020: Croft, Feychting, Hirata, Loughran, Marino, Oftedal, van Rongen, Röösli, Sienkiewicz and Watanabe. These are the ones with the highest centrality, i.e., with the most links to co-authors. However, these authors are also ICNIRP 2020 co-authors, and were also ICNIRP Commission members in 2020. Hence, in many instances they are referring to themselves to underpin ICNIRP's 2020 guidelines.

In the references given in ICNIRP 2020, we also often find Jokela, who was also a co-author of ICNIRP 2020 and an ICNIRP affiliate, and Laakso, an ICNIRP affiliate.

We also find the two IEEE C95.1 2019 [13] co-authors Ziskin and Foster. IEEE C95.1 are the EMF-guidelines published by IEEE in the USA, most recently in 2019, i.e., issued a year before ICNIRP 2020. The IEEE C95.1 standard is the American forerunner to ICNIRP 2020. The IEEE guidelines are based on the thermal-only paradigm, as is ICNIRP 2020. Other authors of IEEE C95.1 2019, as well as of ICNIRP 2020 found in the graph in Figure 2, are Croft, Hirata, Laakso and van Rongen. (The co-authorship relations of IEEE C95.1 2019 are **not** included in the graph.)

The pattern emerging is thus: *ICNIRP affiliates and ICNIRP 2020 authors are heavily involved in literature referenced in ICNIRP 2020 to underpin it*.

Hence, we see a self-referencing circuit appearing.

In Pattern 2 we take a closer look at the committee members co-authoring the literature reviews, while in Pattern 3 we investigate the co-authorships of the peer reviewed papers.

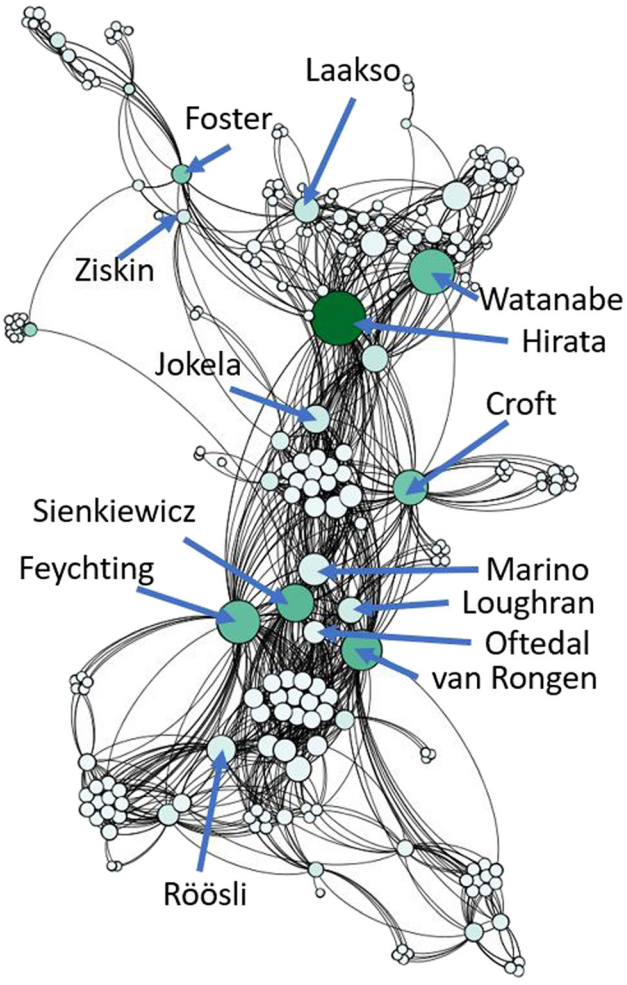

Figure 2: A visualization of the complete network of co-authorship relations originating from the ICNIRP affiliates found as authors in the ICNIRP 2020 referenced literature.
The nodes represent authors and the edges co-authorship relations. The size and color of the nodes reflect the number of co-authorship relations, i.e., the nodes' centrality. Some of the most central nodes are marked with author names to show where some of the authors mentioned in this paper are located in the network (The visualization was made with the Gephi graph tool, names and arrows added manually).

Pattern 2: ICNIRP 2020 authors are involved in all literature reviews referenced in ICNIRP 2020 to underpin it

In addition to building on ICNIRP's own earlier guidelines and ICNIRP reviews, the conclusions in ICNIRP 2020 are primarily underpinned by seven major literature reviews on the relationship between RF EMF and health. ICNIRP 2020 [2 p. 517] presents these reviews as follows:

> *The World Health Organization (WHO) has undertaken an in-depth review of the literature on radiofrequency electromagnetic fields (EMFs) and health, which was released as a Public Consultation Environmental Health Criteria Document in 2014. This independent review is the most comprehensive and thorough appraisal of the adverse effects of radiofrequency EMFs on health. Further, the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), a European Commission initiative, also produced a report on potential health effects of exposure to electromagnetic fields (SCENIHR 2015), and the Swedish Radiation Safety Authority (SSM) have produced several international reports regarding this issue (SSM 2015, 2016, 2018). Accordingly, the present guidelines have used these literature reviews as the basis for the health risk assessment associated with exposure to radiofrequency EMFs rather than providing another review of the individual studies.*

The impression given here is that these literature reviews are authored by others than ICNIRP and its affiliates, i.e., that they have been produced by independent committees. We assessed the claim that the first document referred to as (WHO) is as independent as ICNIRP 2020 claims. We also checked if any ICNIRP affiliates were members of the committees authoring the other literature reviews. In addition, ICNIRP 2020 refers to two reports from the Health Council of the Netherlands in the discussion on cancer risks from RF EMF. These reports were also checked as to their independence from ICNIRP.

As shown below, all these reviews have been carried out by committees having several ICNIRP affiliates as participants, and they all have ICNIRP 2020 co-authors as members. See Table 1 and Figure 3 which show ICNIRP affiliates who are members of more than one of these committees.

The literature reviews referenced in ICNIRP 2020 are:

1. A draft WHO monograph [11], prepared by a committee under The International EMF Project in the WHO, an office strongly tied to ICNIRP, and drawing regularly on ICNIRP personnel. In ICNIRP 2020 [2 Appendix B, p. 517], this draft WHO monograph is referred to as the "*World Health Organization. Radiofrequency fields; Public Consultation Document, released October 2014. Geneva: WHO; 2014.*" The draft is presented as "independent", and as "*the most comprehensive and thorough appraisal of the adverse effects of radiofrequency EMFs on health*". However, from a presentation given by the chair of the committee, van Deventer [14], we learn that of the six members of the core group, 5 were members of ICNIRP. 3 of these were also authors of ICNIRP 2020. Hence, the WHO 2014 document cannot reasonably be termed "independent" but should rather be considered a product under the control of ICNIRP affiliates.

Table 1: Persons who were members of more than one of the committees authoring ICNIRP 2020 and the literature reviews referenced in ICNIRP 2020. Columns show memberships in the authoring committees of ICNIRP 2020 Guidelines and/or the seven major literature reviews and the ICNIRP reports referred to in ICNIRP 2020. Rows list persons who were members of more than one of the committees. Memberships are indicated as follows: X: member of the committee; "SEG": former or current member of ICNIRP Scientific Expert Group; "2020": ICNIRP-member and author of ICNIRP 2020; "CG": member of the WHO Core Group; "CH": Committee head; "SS": Scientific secretary; "Key author": person being identified as such in our network analysis presented in Pattern 4 below.

Name	ICNIRP	WHO 2014	SCENIHR 2015	HCN 2014 2016	SSM 2015, 2016, 2018	Key author
Auvinen	SEG		X			
Feychting	2020	CG				X
Juutilainen	SEG	X				X
Loughran	2020	X				
Marino	2020	X				
Mann	SEG	CG				
Mattsson	SEG		CH to 2013			
Oftedal	2020	CG				
Paulides	SEG			X		X
Van Rongen	2020	CG		SS	X	
Röösli	2020	X			X	
Scarfi	SEG	CG	X		X	
Sienkiewicz	2020	X	X			X
Schüz			X			X
Samaras			CH from 2013			X
Van Deventer	Observer	Leader			X	
Danker-Hopfe			X		X	
Huss			X	X	X	

Furthermore, the draft WHO monograph is a *draft* document. The draft made it no further than to the consultation and comments process as it triggered a storm of protests from researchers around the world, e.g., for being heavily biased. ICNIRP 2020 conveys the impression that the report was completed and published by the WHO. At the time of this writing, the draft appears to have been completely removed from the internet. We have found a copy of several chapters of the draft. Every page is marked "Draft" and "THIS IS A DRAFT DOCUMENT FOR PUBLIC CONSULTATION. PLEASE DO NOT QUOTE OR CITE". This referenced document can therefore not in any way to be considered a WHO publication, but a private publication by a small group of authors dominated by ICNIRP affiliates.

2. Report from the European Commission's SCENIHR Committee [12]: "Potential health effects of exposure to electromagnetic fields (EMF)."
   This report has been heavily criticized for bias and errors, e.g., in very comprehensive analyses by several prominent researchers and analysts [15–18]. E.g., Pall's review [16] finds 22 literature reviews from the relevant years SCENIHR claims to have evaluated thoroughly (2009–2013) that all contradict SCENIHR's conclusions. Out of these 22, 20 are not mentioned in the SCENIHR report [12], and the remaining two are rejected.
   The working group of the SCENIHR Committee included several ICNIRP affiliates and was headed by such until 2013 (Mattson), when an IEEE C95.1. 2005 co-author Dr. Theodoros Samaras took over.

[Correction added after online publication 27 June 2022: when an IEEE C95.1. 2019 co-author (Samaras) took over, page 5, was updated as follows: when an IEEE C95.1. 2005 co-author Dr. Theodoros Samaras took over.]

3. Three annual literature reviews from the Swedish Radiation Protection Authority's scientific committee on electromagnetic fields (references SSM 2015, 2016, 2018 in ICNIRP 2020).
   As shown in Table 1, several members of this committee are ICNIRP affiliates, two of whom are authors of ICNIRP 2020.

4. Two reports from the Health Council of the Netherlands (references HCN 2014 and 2016 in ICNIRP 2020).
   These documents are used as the basis for claiming that there is no risk of cancer from athermal EMF exposure. Head of ICNIRP until spring 2020 as well as ICNIRP 2020 author, Eric van Rongen, has over an

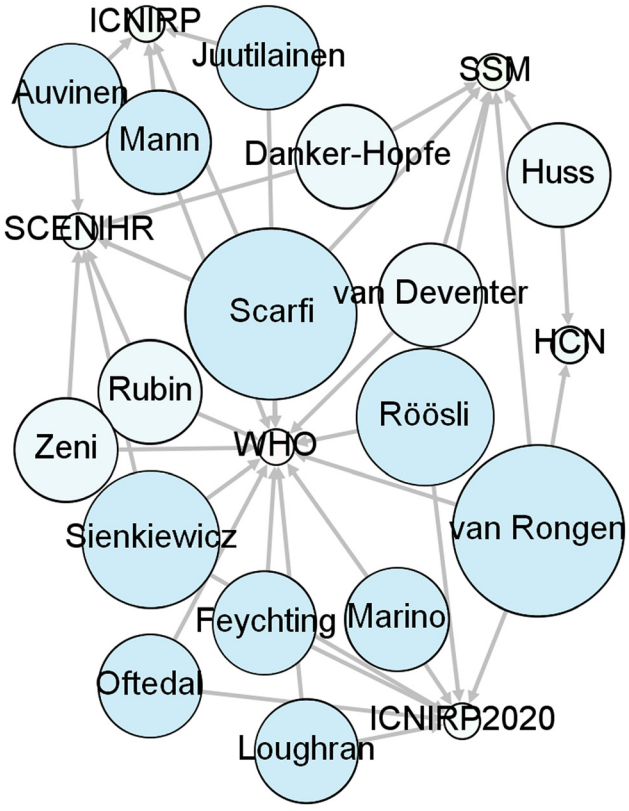

Figure 3: Relations between the literature review committees and persons who are members of more than one such committee. The committees are seen as small nodes with the name of the committee. Members of more than one committee are shown as larger nodes, with size according to the number of committee memberships. The committee node marked "ICNIRP" has relations to ICNIRP affiliates who are not authors of ICNIRP 2020. ICNIRP affiliated persons: blue nodes.

> extended period of time held key positions in HCN, e.g., as "scientific secretary". Van Rongen had the role of "scientific secretary" for the two HCN reports. The chair of the HCN committee at the time the reports were written, van Rhoon, is a member of the ICNIRP co-authorship network presented in Pattern 1, where also van Rongen is found.

Table 1 is a presentation of the multi-membership in committees by ICNIRP affiliates and others. For more information on such overlapping memberships see e.g., [4, 19, 20]. Figure 3 visualizes the multi-memberships in the committees in a graph format.

We see that the report from WHO, explicitly described as "independent", is the node with the highest number of ICNIRP affiliates and ICNIRP 2020 authors connected. The other reports all have ICNIRP affiliates and ICNIRP 2020 authors behind them but are fewer in number. However, with such a clear presence of ICNIRP affiliates in the committees, with their stature and influence, the perspective, methods and findings of the committees are influenced, as is also the independence of the reviews.

The pattern emerging is this: *ICNIRP 2020 authors are involved in all literature reviews referenced in ICNIRP 2020 to underpin it*. Hence, we see the self-referencing circuit becoming more dominant than in Pattern 1: No literature reviews other than those in which the ICNIRP 2020 authors have participated in themselves are mobilized to form the base of the ICNIRP 2020 Guidelines.

All literature reviews referenced in ICNIRP 2020 support the thermal-only paradigm. ICNIRP 2020 does not refer to a single one of the long line of reviews and studies rejecting the thermal-only paradigm, nor to other extant guidelines on limiting exposure based on non-thermal effects. Three major reports of this category can serve as examples: [21–23].

Such reports do not use ICNIRP's method for research evaluation, a method which is thoroughly described in an ICNIRP report from 2002 [24]. In ICNIRP 2020 this method is expressed in a definition of what it takes to be a "*scientifically substantiated*" proof of health effects [2 p. 484]. ICNIRP 2020 states that when assessing research, the aim is to identify [2 p. 484] "*the adverse health effect threshold; the lowest exposure level known to cause the health effect*.", and furthermore, ICNIRP's method for finding the threshold [2 p. 486] is presented:

> *… for each adverse effect that was substantiated, both the mechanism of interaction and the minimum exposure required to cause harm were determined …*

From this we see that ICNIRP's assessment criteria are aimed at picking out studies which can be used to calculate exposure thresholds. This implies that ICNIRP requires that such studies must provide measurements showing a clear positive (and mainly linear) dose-response relationship from which such threshold values can be calculated. ICNIRP also expresses the need to have a physics description of the mechanism that causes the dose-response relation so that the thresholds can be defined in a physics-style formula. The only health effect from RF EMF which in ICNIRP's view meets these criteria is tissue heating. Therefore, ICNIRP's calculations of threshold values only take this effect into consideration.

Assessment criteria such as these from ICNIRP are frequently criticized for being too "mechanistic", i.e., too physics oriented, and too little biology oriented [18], and therefore not suitable for evaluating research assessing health risks other than those conforming to such "mechanistic" criteria, nor are they suitable for precautionary approaches.

Such "mechanistic" criteria are also criticized for being used tactically in a similar way to those used by the tobacco industry to deny reasonably solid biologic findings [25, 26] and as a bulwark against precautionary approaches. The dismissal by ICNIRP of the three major reports mentioned above [21–23] could be considered examples of such strategies: They are all ignored as they use scientific assessment criteria from biology, which are quite different from ICNIRP's mechanistic requirements for findings to be considered "*scientifically substantiated*" proofs of health effects.

ICNIRP 2020 prescribes that for a study to be "*taken as 'evidence' and used for setting exposure restrictions*", it must be "*consistent with current scientific understanding*" [2 p. 484], which in ICNIRP's view means that it must comply with the thermal-only view. ICNIRP has long been criticized for using such an assessment criterion, seemingly built for a "constructive dismissal" approach [20, 27, 28], which, among other things, implies placing the burden of proof on the one challenging the thermal-only paradigm.

Through such a "constructive dismissal" approach, ICNIRP seems to have fostered a self-referential culture by employing a strictly formal scientific legitimation whereby all opposing literature reviews can be rejected or ignored. Hence, not even mentioning or discussing this literature appears from such a perspective to be justified by this inner logic. For this reason, the authors of ICNIRP 2020 only reference literature reviews they have participated in themselves, as hardly any other reviews use ICNIRP's mechanistic assessment criteria.

Pattern 3: <u>All</u> scientific papers used to underpin ICNIRP 2020 are from the same co-author network centered around ICNIRP affiliates

In sum, we found 78 unique references to peer reviewed papers from the ICNIRP co-authorship network presented in Pattern 1.

Of these 78 papers, 57 have ICNIRP affiliates as co-authors. Of the 21 papers without ICNIRP affiliated co-authors, 12 of them have IEEE affiliates as co-authors, leaving only nine peer reviewed papers without any authors being ICNIRP or IEEE affiliates. Seven of these nine papers focus on SAR modelling, with the dosimetrician Dimbylow as first author. One of the nine is with co-author Fujiwara, who is also co-author of 12 papers with the ICNIRP 2020 author Hirata, and finally, one of the nine has Schüz as its first author, where he is also closely tied to the ICNIRP network.

We questioned whether these 78 papers were the only ones used to support the ICNIRP 2020 guidelines' thermal-only paradigm position. We therefore searched through the ICNIRP 2020 references for papers used to support ICNIRP 2020's position, but with no co-authors from the ICNIRP co-authorship network. While we found four such papers, we also found that they are either indirectly ICNIRP-affiliates related, or used on false premises as support:

The four papers are the ICNIRP 2020 references (Eltiti et al. [29]), (Sommer et al. [30]), (Taberski et al. [31]) and (Vijayalaxmi and Prohoda [32]). In the following we refer to these papers with the author names used in ICNIRP 2020 references combined with our reference, e.g., "(Eltiti et al. [29])".

First, we checked if any of the (co-)authors of these papers have any links to the ICNIRP affiliates. We did so by searching for co-authorships in other papers than the ones referenced in ICNIRP 2020. We also checked the four papers' scientific value and if they were correctly quoted.

We sum up our findings before going into more detail:

Papers number 2 and 3 below, (Sommer et al. [30]) and (Taberski et al. [31]), are only semi-independent: The co-authors have several co-authorships with many ICNIRP affiliates. The conclusion of (Sommer et al. [30]) runs contrary to evidence, e.g. [33]. (Taberski et al. [31]) provides no relevant proof of ICNIRP's claims. These papers can therefore not be considered to provide scientifically sound support of ICNIRP's claims.

Paper number 1 below (Eltiti et al. [29]) uses an investigation method which is no longer accepted, not even by ICNIRP affiliates [34], and draws conclusions which run contrary to evidence, e.g. [35]. It cannot be considered to express scientific consensus, and therefore provides no scientifically sound support of ICNIRP's claim.

The conclusion of paper number 4 below (Vijayalaxmi and Prohoda [32]) is not cited correctly, but misinterpreted, into an unwarranted support of ICNIRP's view of "no substantiated evidence" of adverse health effects besides thermal. It therefore provides no scientifically sound support of ICNIRP's claim.

Thus, we find that no independent papers cited as underpinning ICNIRP 2020 in fact do so.

From this we see that all papers legitimately cited by ICNIRP 2020 to underpin it have been authored by people within the ICNIRP co-authorship network.

The pattern emerging is thus: *All scientific papers used to underpin ICNIRP 2020 come from the same co-author network centered around ICNIRP affiliates*.

Below we present the four papers discussed above:

1. (*Eltiti et al.* [29])*: an independent paper accepted by ICNIRP 2020, but not by the scientific community*

The (Eltiti et al. [29]) paper is used in ICNIRP 2020 to argue that electrosensitivity (referred to as "Idiopathic Environmental Intolerance attributed to EMF", IEI-EMF) is a nocebo reaction, i.e., that all adverse athermal effects are explainable as purely psychological reactions.

From ICNIRP 2020 we quote:

> *These experimental studies provide evidence that "belief about exposure" (e.g., the so-called "nocebo" effect), and not exposure itself, is the relevant symptom determinant (e.g., Eltiti et al. 2018; Verrender et al. 2018).*

Here we find two references, with first authors Eltiti and Verrender:

Verrender has a paper with the ICNIRP affiliates Lougran and Croft among the ICNIRP referenced papers (Lougran et al. 2012 in ICNIRP 2020). An internet search shows that Verrender has also published with several other ICNIRP affiliates on various occasions. Verrender is therefore clearly linked to the ICNIRP network.

We consider (Eltiti et al. [29]) to be independent, as we have not found any co-publications between ICNIRP affiliates and Eltiti or any of her co-authors on this paper. We found that Eltiti is affiliated with UK and USA research institutions, and that she and her co-authors have published a number of papers, all claiming IEI-EMF to be nocebo. Such a view is subject to heavy criticism of the methodology used in the tests, and for the lack of solid evidence for such conclusions, e.g., by ICNIRP 2020 co-author Oftedal in the co-authored paper [34]. Other critiques of the view that IEI-EMF is a pure psychological nocebo reaction are based on strong evidence that EHS/IEI-EMF is a biophysical reality [35]. Hence, Eltiti's paper does not constitute well-founded support.

2. *(Sommer et al.* [30]*): a sole semi-independent paper with "no finds" used as proof, while findings are neglected*

In ICNIRP 2020 this paper is cited as proof that no harmful effects from long-term exposures to EMF on fertility, reproduction, or development relevant to human health have been substantiated.

From ICNIRP 2020 (p. 522) we quote:

> *In particular, a large four-generation study in mice on fertility and development using whole-body SAR levels up to 2.34 W kg^{-1} found no evidence of adverse effects (Sommer et al. 2009). Some studies have reported effects on male fertility at exposure levels below this value, but these studies have had methodological limitations and reported effects have not been substantiated.*

In fact, Sommer et al. [30] conclude that:

> *In summary, the results of this study do not indicate harmful effects of long-term exposure of mice to UMTS over several generations.*

ICNIRP 2020 correctly forwards the general statement that no effects have been found in this study. However, no other research results are presented or discussed. This sole paper is used as scientific proof that no such effects exist, even though "some studies" have shown effects. None of these "some studies" are referenced, nor discussed or mentioned, neither is the criticism levelled against them specific enough to be evaluated.

As can be seen from the review of this topic undertaken in a recent report from the "European Parliamentary Research Service, Scientific Foresight Unit (STOA)" [33], there is no lack of good research. The STOA report is a comprehensive study which followed a methodology for evaluating the quality of research published by WHO IARC [36]. After searching international research databases, the STOA report [33] found a large number of papers on the topic, and sorted out the 30 relevant peer reviewed papers they found to be of good quality. None of these have been considered by ICNIRP 2020. The STOA researchers concluded that these 30 papers provide clear evidence of EMF having negative effects on male reproduction.

We did not find any co-authorship between Sommer and ICNIRP affiliates. However, we found that Lerchl, who is a co-author of this paper and with whom Sommer often collaborates, has himself been a member of the German Commission on Radiation Protection (SSK) and chairman of their Committee on Non-Ionizing Radiation, where also key author Schüz has been a member. SSK is a sponsor of ICNIRP and houses ICNIRP's office. Lerchl has a history of defending the thermal position, and has collaborated with several ICNIRP affiliates, e.g., he has authored a paper [37] with six ICNIRP affiliates: Repacholi, Röösli, Sienkiewicz, Auvinen, d'Inzeo, and Lagroye. Lerchl is therefore also clearly linked to the ICNIRP network.

The paper (Sommer et al. [30]) is not within the ICNIRP co-authorship network, as we defined it purely on the basis of the ICNIRP 2020 references. If taking a broader view, as we just did above, also this paper, used by ICNIRP 2020 to find support for its position, is clearly linked to the network, and can therefore be considered just semi-independent.

Sommer et al. [30], a semi-independent paper at best, is used in ICNIRP 2020 as a proxy to circumvent large,

international studies which a number of independent researchers have found to provide clear and significant evidence of links between athermal levels of EMF exposure and effects on fertility. This is illegitimate scientific behavior.

3. (*Taberski et al.* [31]): *a semi-independent paper which is irrelevant, is used by ICNIRP 2020 as support*

Taberski et al. [31] is used as support in ICNIRP 2020 in the section "*Cardiovascular system and autonomic nervous system and thermal regulation*", the only place where effects of EMF on these important body systems are discussed.

Among the authors of this paper, we once again find Lerchl, whose connections to the ICNIRP network have been presented above. A simple search also reveals that Taberski and Lerchl have a number of co-authored papers in common. Hence, also this paper can only be considered to be semi-independent.

ICNIRP 2020 argues that the only mechanism by which EMF can affect the cardiovascular system and the autonomic nervous system is by a rise in the core body temperature. It first refers to literature which shows that a rise in the core body temperature – not produced by EMF – affects these systems. Then it cites literature which has shown a rise in this temperature for animals exposed to EMF, but dismisses these studies since the levels of exposure in the experiments cited were very high, often causing the animals' death. Then, ICNIRP 2020 references a paper which we consider to be clearly irrelevant, since cause and effect are here inverted, quoted by ICNIRP 2020 as follows:

> *Taberski et al. (2014) reported that in Djungarian hamsters no body core temperature elevation was seen after whole-body exposure to 900 MHz fields at 4 W kg^{-1} with the only detectable effect a reduction of food intake (which is consistent with reduced eating in humans when body core temperature is elevated).*

The abstract for this paper (Taberski et al. [31]) shows that the researchers primarily investigated a method for "Noninvasive assessment of metabolic effects":

> *The results demonstrate the usefulness of our methods for experiments dealing with metabolic effects of RF-EMF exposure in rodents. They also confirm the assumption that even though the metabolism is reduced at high SAR levels, the body core temperature is being kept constant by the energy uptake from the RF-EMF exposure which is able to physiologically compensate for the reduced metabolism.*

In other words, what (Taberski et al. [31]) claim to have found is that the heating from EMF exposure compensated for the fall in temperature created by the rodents' loss of appetite from being radiated.

Based on this paper, which the authors of ICNIRP 2020 found relevant, ICNIRP 2020 concludes [2 p. 521]:

> *Few epidemiological studies on cardiovascular, autonomic nervous system, or thermoregulation outcomes are available. Those that are, have not demonstrated a link between radiofrequency EMF exposure and measures of cardiovascular health.*
>
> *In summary, no effects on the cardiovascular system, autonomic nervous system, or thermoregulation that compromise human health have been substantiated for exposures with whole-body average SARs below approximately 4 W kg^{-1}, with harm only found in animals exposed to wholebody average SARs substantially higher than 4 W kg^{-1}.*

Bearing this in mind, ICNIRP 2020 argues that the core body temperature will not rise – and that therefore – based on this single paper – there will be no effects on the cardiovascular and autonomic nervous systems caused by athermal EMFs. Using the conclusion of one single paper testing a different hypothesis – one of a relation between EMF and appetite – is not in any way scientifically sound, and it does not give substantiated evidence to support the conclusions that only thermal effects need to be considered.

Using this paper as scientific evidence for claiming that elevated core temperature is the sole potential cause of health effects on these body systems is clearly without merit. It is in stark contrast to the view that EMFs themselves can interact with electrical signaling in both of these body systems, forwarded and underpinned by the many relevant papers on this topic, see e.g., the almost 200 (!) literature reviews showing the athermal effects referred to in Ref. [7].

4. (*Vijayalaxmi and Prohoda* [32]): *"inconsistent results"; is (mis)presented as "no substantiated evidence"*

The fourth independent paper that is not rejected is presented as follows in ICNIRP 2020 [2 p. 522]:

> *Although there are reports of effects of radiofrequency EMFs on a number of these endpoints, there is no substantiated evidence of health-relevant effects (Vijayalaxmi and Prihoda 2019).*

From the abstract of (Vijayalaxmi and Prohoda [32]), we quote:

> *Overall, the data are inconsistent; while some studies have suggested significantly increased damage in cells exposed to RF energy compared to unexposed and/or sham-exposed control cells, others have not.*
>
> …
>
> *Overall, the results from this study underscore the importance of including quality control measures in investigations so that the resulting data are useful, nationally and internationally, in evaluating "potential" health risks from exposure to RF energy.*

Here we see that the paper's clear conclusion that data inconsistencies exist in this field of research is presented in ICNIRP 2020 as proof of there being "no substantiated evidence" of health effects. Due to the diversity and complexity of biological systems and life environments, inconsistent outcomes are the rule, not the exception in life sciences. Inconsistent outcomes might still very well form substantiated evidence. To claim that "inconsistent data" means "not substantiated" can only be justified if disregarding this fact. This paper is misused by ICNIRP 2020 to falsely underpin it.

Pattern 4: A small and tight network of just 17 authors behind all the literature used to underpin ICNIRP 2020

The ICNIRP co-authorship network presented in Figure 2 showed some authors who were more central than others. This led us to investigate the power concentration in this network. We first investigated the authorship behind the 78 network papers. A simple measure of power concentration is the size of the minimal set of (co-)authors needed to include authorships of all the 78 papers:

1. For each of the 78 papers we would find at least one of the co-authors of the paper in this subset of authors, and
2. all authors in this subset would be the sole co-author from this subset in at least one of the 78 papers.

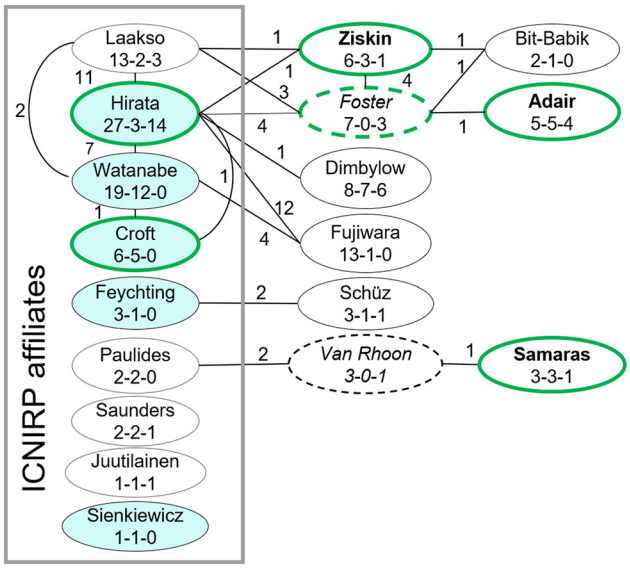

Figure 4: The 16 "key authors" (ovals) and their co-authorship relations (edges) within the 78 ICNIRP network papers, their affiliations and paper authorship roles.
This set of "key authors" has been selected from the 78 papers' (co-)authors so that for each of the 78 papers we would find at least one of the co-authors of the paper in this subset of authors, and all authors in this subset would be the sole co-author from this subset in at least one of the 78 papers. Affiliations: ICNIRP affiliates (within the rectangle), ICNIRP 2020 author (blue oval), IEEE C95.1 authors (thick green border). Ovals with dotted border are not key authors but links between ICNIRP affiliates and key authors who are not directly linked through co-authorships in any of the 78 papers. Edge numbers: Number of co-authored papers. Numbers in ovals signify number of papers where the author is: <co-author> – <sole key author> – <first author>.

We found this minimal core set of authors to consist of just 16 authors. We labelled them "key authors", demonstrating a highly concentrated authorship behind the references used by ICNIRP 2020 to underpin it.

Figure 4 presents the 16 key authors and their co-authorship within the 78 network papers.

Van Rhoon and Foster are shown in Figure 4, even though they are not key authors: They are always co-authors with one or more of the 16 key authors. However, they are link nodes in the network of key authors. Van Rhoon was chair of the committee authoring the Dutch HCN reports referenced in ICNIRP 2020, hence also an important link to van Rongen, ICNIRP's previous chair and scientific secretary of HCN, a very central node as shown in Figure 2.

Of the 16 key authors, five are also authors of ICNIRP 2020 as well as ICNIRP affiliates. Four more of the key authors are ICNIRP affiliates. Hence, there are nine ICNIRP affiliates among the 16 key authors, again demonstrating the circularity: To underpin ICNIRP 2020, the authors and only refer to papers authored by themselves and other ICNIRP affiliates, and a few close collaborators.

For the remaining seven key authors, we find that three are authors of the IEEE C95.1 2019 Guidelines.

ICNIRP 2020 authors Hirata and Croft are co-authors of both guidelines, and Croft is head of ICNIRP. This demonstrates strong co-authorship relations between the world's two main guidelines for RF EMF exposure levels – both based on the thermal-only paradigm.

Only four of the 16 key authors are neither affiliated with ICNIRP, nor with the IEEE. These four key authors are sole key authors of 10 of the 78 ICNIRP co-authorship network papers, i.e., 12% – a clear minority of the papers. This means that a large majority of the papers – 88% – have the 12 key authors affiliated with ICNIRP and/or IEEE as co-authors.

Furthermore, the 16 key authors are also co-authoring the referenced committee reports, except those from the Swedish Radiation Protection Authority (SSM). For also these to be included, it suffices to add either van Rongen or

Röösli to the set of key authors. They are both ICNIRP members, hence affiliates, and they are ICNIRP 2020 authors.

Hence, just 17 people are sufficient to cover all the 78 ICNIRP co-authored papers, the six ICNIRP publications and the seven literature reviews used to underpin ICNIRP's thermal-only view, as well as ICNIRP 2020 itself. Again, we have demonstrated a situation of circular references, where the most essential part of the underpinning of ICNIRP 2020 is provided by a close-knit group of a few collaborating researchers with extensive co-authorship. This circularity and power concentration is even more thought provoking when considering this group's heavy involvement also in the authorship of the IEEE C95.1 RF EMF guidelines.

The pattern emerging is thus: *A small and tight network of just 17 authors is behind all the literature used to underpin ICNIRP 2020*.

The following textual summaries about the key authors reveal the extreme tightness of their co-authorship relations. The key authors are presented in alphabetical order, with their committee memberships and including their relationship to IEEE. Eighteen people are listed, as we include both van Rongen and Röösli, as both are candidates for the 17th position of key author.

We only provide numbers of the key authors' authorship in ICNIRP network papers as full references would include all 78 references in the ICNIRP 2020 reference list. Their papers are easily identifiable by searching there for the author's last name.

1. Eleanor R. Adair, a co-author of IEEE C95.1 2005 Guidelines, is the author of 5 of the referenced papers, sole key author of five and first author of four. Deceased in 2013, since the 1970s she was a radiation researcher advocating thermal-only based exposure standards. Adair is linked to the network through co-authorship with Kenneth R. Foster, who is co-author with ICNIRP affiliates Laakso and Hirata in the referenced papers. Foster is a co-author of both the IEEE C95.1 2019 and 2005 Guidelines and an author of seven of the ICNIRP 2020 referenced papers. Two ICNIRP 2020 co-authors and three IEEE C95.1 2019 co-authors are co-authors of IEEE C95.1 2005 together with Adair.
2. Giorgi Bit-Babik, at the Corporate EME Research Laboratory, Motorola Labs, USA, is the author of two referenced papers, sole key author of 1 and first author of none, and co-author with Ziskin and Foster, who are both authors of the IEEE C95.1 2019 Guidelines.
3. Rodney Croft, psychologist, at present ICNIRP chair, co-author of ICNIRP 2020, also a co-author of the IEEE C95.1 2019 Guidelines. He is the co-author of six referenced papers, five as sole key author and first author of none.
4. Peter J Dimbylow is a co-author of eight referenced papers, seven of which he is sole key author and six of which he is first author. He is linked to the network through co-authorship with ICNIRP 2020 author Hirata, a central key author, see below.
5. Maria Feychting, as of 2020 member of the ICNIRP Commission and co-author of ICNIRP 2020, also member of the WHO core group. She is co-author of three referenced papers, sole key author of one, and first author of none.
6. Osamu Fujiwara is co-author of 13 referenced papers of which 12 are in co-authorship with ICNIRP 2020 co-author Hirata. Fujiwara is sole key author of one paper – the one without Hirata – and first author of none.
7. Akimasa Hirata, ICNIRP Commission member and co-author of ICNIRP 2020, also a co-author of the IEEE C95.1 Guidelines. He is a co-author of 27 of the referenced papers, sole key author of three and first author of 14. He is the person with the most co-authorship relations in the ICNIRP co-authorship network.
8. Jukka Juutilainen is an ICNIRP affiliate and member of the WHO committee. He is the first author of one paper, where he also is the sole key author.
9. Ilkka Laakso is an ICNIRP affiliate. He is a co-author of 13 referenced papers, sole key author of two and first author of three.
10. Margarethus Paulides is an ICNIRP affiliate and member of the HCN. He is the co-author of two referenced papers, of which he is also the sole key author, and first author of none.
11. Eric Van Rongen, ICNIRP Commission member and co-author of ICNIRP 2020, not a key author of any of the peer reviewed papers, but committee member of SSM and therefore a candidate for the 17th key author position needed to also cover SSM. Moreover, scientific secretary for HCN and co-author of the referenced WHO draft.
12. Martin Röösli, ICNIRP Commission member and co-author of ICNIRP 2020, not a key author of any of the peer reviewed papers, but committee member of SSM and therefore a candidate for the 17th key author position needed to also cover SSM. Also co-author of the WHO draft.
13. Theodoros Samaras is a co-author of the IEEE C95.1 2005 Guidelines and the chair of the EU SCENIHR committee from 2013. He is the co-author of three referenced papers, all of which he is the sole key author. He is the first author of one paper.

[Correction added after online publication 27 June 2022: Theodoros Samaras is a co-author of the IEEE C95.1 2019 Guidelines and the chair of the EU SCENIHR committee

from 2013, page 11, was updated as follows: Theodoros Samaras is a co-author of the IEEE C95.1 2005 Guidelines and the chair of the EU SCENIHR committee from 2013.]

14. Richard D. Saunders is an ICNIRP affiliate and the co-author of two referenced papers for which he is the sole key author, and he is a first author of one of them.
15. Joachim Schüz is at present branch head of the Section of Environment and Radiation at the IARC (WHO's cancer research institute) and has worked and co-authored with ICNIRP affiliates on several occasions. He is a co-author of the EU SCENIHR 2015 report, a co-author of three referenced papers in ICNIRP 2020, sole key author of one, and first author of one.
16. Zenon Sienkiewicz is an ICNIRP affiliate, a co-author of ICNIRP 2020, and a member of both the WHO and EU SCENIHR committees. He is a co-author of a single referenced paper where he is also the sole key author, and he is first author of none.
17. Soichi Watanabe is a member of the ICNIRP Commission and co-author of ICNIRP 2020. He is a co-author of 19 referenced papers and sole key author of 12, and first author of none.
18. Marvin Ziskin is a co-author of the IEEE C95.1 2019 Guidelines and co-author of six of the referenced papers, sole key author of three and first author of one.

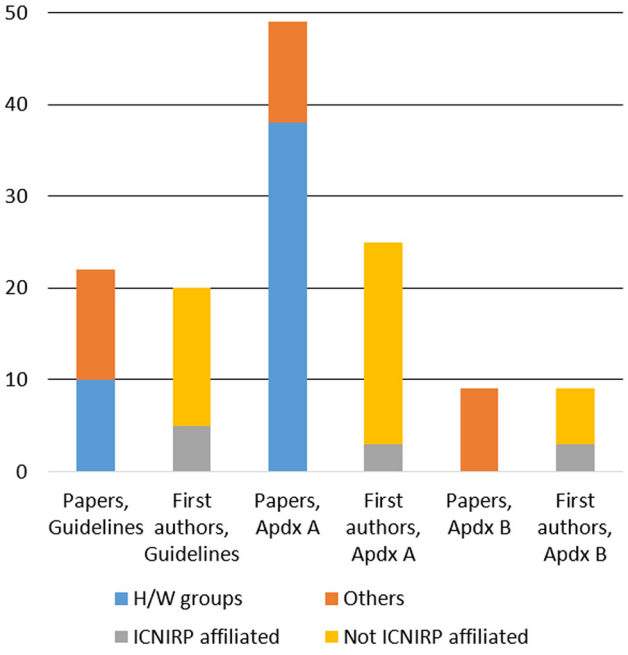

Figure 5: In the referenced papers underpinning ICNIRP 2020, few first authors are ICNIRP affiliated.
Columns show counts of referenced papers and of first authors in the ICNIRP 2020 Guidelines, Appendices A and B. Gray shows that ICNIRP affiliates are in a clear minority among first authors in all these three parts of ICNIRP 2020. Blue shows papers from the Japanese research groups, led by the two ICNIRP Commission members and ICNIRP 2020 authors Hirata and Watanabe (H/W). These papers dominate the ICNIRP network papers in Appendix A and comprise almost half of the referenced papers in the Guidelines.

Pattern 5: The spread of first authors gives a false impression of broad support

In Pattern 4 we showed a strong power concentration of just 16 authors behind the 78 ICNIRP network papers with 88% of the papers having ICNIRP and/or IEEE affiliates as co-authors.

Is such a concentration of power, with a domination by ICNIRP and IEEE affiliates, also to be found among the first authors of these 78 papers?

We investigated this question and found that the distribution of first authors of these referenced papers in the ICNIRP 2020 Guidelines and the two Appendices is much more varied (see also Figure 5):

- In all, the 78 ICNIRP network papers have 45 different first authors. Of these 45, only eight are ICNIRP affiliates, of whom three are authors of ICNIRP 2020.
- Of the 45 first authors, 34 appear only once as a first author. The remaining 11 first authors are first authors of more than one paper. ICNIRP 2020 author Hirata is the first author of 14 papers. Of the remaining 30 papers, 10 authors are first authors of two or more papers.
- In the ICNIRP 2020 Guidelines, there are 22 ICNIRP network papers, with 20 different first authors. Half of the papers have authors from the Hirata and Watanabe research groups, both members of the ICNIRP Commission and authors of ICNIRP 2020 (Columns 1 and 2).
- In the highly technical Appendix A, there are 47 ICNIRP network papers, with 25 first authors. Out of these 47 papers, 38 papers come from the Hirata and Watanabe groups (Columns 3 and 4).
- In Appendix B, there are nine ICNIRP network papers, with nine different first authors.

The many different first authors make ICNIRP 2020 appear to have a broad base in the scientific community, and even more so, the few first authors affiliated with ICNIRP

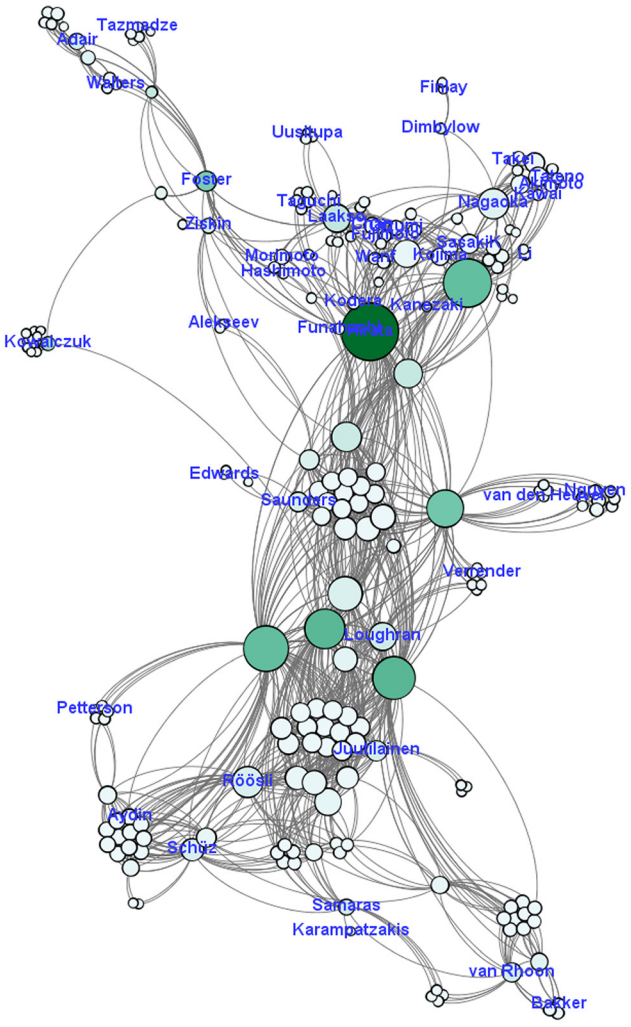

Figure 6: The first authors' positions in the outskirts of the ICNIRP co-authorship network.
This figure shows that the majority of the first authors' have peripheral positions in the network. Compare with Figure 2, showing the ICNIRP affiliates' central positions.

seemingly make it appear that the papers stem from independent sources. However, the many different first authors, mainly non-ICNIRP affiliates, conceal the ties to the ICNIRP affiliates found as co-authors in almost all these papers. Figure 6 depicts this situation: First authors are mainly found in the periphery of the ICNIRP co-authorship network.

The links connecting these first authors and their papers to the ICNIRP affiliated co-authors are not revealed unless one takes a detailed look at the reference list, as we have done (see Patterns 3 and 4 above).

The pattern emerging is thus: *The spread of first authors gives a false impression of broad support.*

Pattern 6: All referenced papers <u>not</u> authored by the ICNIRP co-authorship network are either rejected, misinterpreted to underpin ICNIRP 2020, or offer no scientifically sound support

As shown in Pattern 3, two of the four seemingly independent papers which ICNIRP 2020 cites to underpin its view have authors who are tied into the ICNIRP co-authorship network through extensive co-authorships with ICNIRP affiliates (papers not referenced in ICNIRP 2020). The two remaining papers were, as shown in Pattern 3, misinterpreted, or provided no scientifically sound support of ICNIRP's claim.

In addition to these four papers, we found 11 papers not originating from the ICNIRP co-authorship network. All these papers conclude that there is scientific support for the existence of athermal health effects. All of these 11 referenced papers are rejected in ICNIRP 2020, with general objections such as "methodological weaknesses", "no relevance to humans", or "lack of relationship between dose and effect". In other words, they do not fulfill the requirement of being "*substantiated*", which according to ICNIRP 2020s definition [2. p. 484] includes not having "*sufficient scientific quality*" to provide evidence of EMF being "*harmful to human health*" and not being useful to identify an "*adverse health effect threshold*", i.e., demands that imply that a clearly positive and (mainly) linear dose-response relationship must be clearly demonstrated in humans.

The validity of such demands and such a gross rejection of other research may certainly be questioned. However, engaging in this particular discussion is outside the scope of this paper.

References to the rejected papers are found in ICNIRP 2020 as listed here:

- In the main part of ICNIRP 2020: [38]
- In Appendix A: none
- In Appendix B: [39–48]

All these independent research papers challenge the thermal-only paradigm as they acknowledge and argue that there are adverse sub-thermal bioeffects, referring to findings in which the thermal-only paradigm is insufficiently accounted for. If the conclusions presented in these

11 independent papers were accepted as the basis on which to define RF EMF exposure thresholds, the thresholds would have to be reduced significantly compared to the thermally-based recommendations advocated by ICNIRP and the IEEE in previous as well as present versions of their guidelines.

The pattern emerging is thus: *All referenced papers not authored by the ICNIRP co-authorship network are either rejected, misinterpreted to underpin ICNIRP 2020, or offer no scientifically sound support*.

Conclusions

In the introduction we raised five questions relating to the authorship behind the referenced literature used to underpin the ICNIRP 2020 thermal-only view. Below we repeat the patterns found, answering these questions whilst adding some overarching conclusions.

1. Pattern 1: *ICNIRP affiliates and ICNIRP 2020 authors are heavily involved in literature referenced in ICNIRP 2020 to underpin it*. Figure 2 shows the graph of the complete network of co-authorship relations found in the referenced literature in ICNIRP 2020 originating from the ICNIRP affiliates, displaying that ICNIRP affiliates are the most central nodes of the network, and seven of the most central nodes being ICNIRP 2020 authors.
   Pattern 4: *a small and tight network of just 17 authors is behind all the literature used to underpin ICNIRP 2020*. Of these 17, 10 were ICNIRP affiliates, of whom six were also authors of ICNIRP 2020. Five of these 17 were IEEE C95.1 2019 authors, two of whom were also ICNIRP 2020 authors.
2. Pattern 2: *ICNIRP 2020 authors are involved in all the literature reviews referenced in ICNIRP 2020 to underpin it*. In addition to the ICNIRP 2020 authors, these committees are manned by several other ICNIRP affiliates.
3. Pattern 3: *All scientific papers used to underpin ICNIRP 2020 are from the same co-author network centered around ICNIRP affiliates*.
   Only four papers were found to be used to underpin ICNIRP 2020 that were not linked to the ICNIRP co-authorship network. Of these four, a simple internet search revealed that two of them have authors who have co-authored several papers with ICNIRP affiliates and thus cannot be seen as independent from ICNIRP. The two last were misinterpreted to underpin ICNIRP 2020 or offered no scientifically sound support.
4. Pattern 5: *The spread of first authors gives a false impression of broad support*. While there is a high variation of first authors, most of them not affiliated with ICNIRP/IEEE, a tight network of just 16 key authors, dominated by ICNIRP and IEEE affiliates, is involved in *all the papers* used to underpin ICNIRP 2020 (Pattern 4). Moreover, in the co-authorship network (Pattern 1) ICNIRP affiliates are found as central nodes, while most first authors are peripheral in the network.
   Intentionally or not, the domination of ICNIRP affiliated authorship is blurred by the practice of having many different non-affiliates as first authors. This conceals the fact that effectively all referenced papers used to support ICNIRP 2020 originate from a network of researchers completely dominated by ICNIRP affiliates and a few who are closely related.
5. Pattern 6: *All referenced papers not authored by the ICNIRP co-authorship network are either rejected, misinterpreted to underpin ICNIRP 2020, or offer no scientifically sound support*.

Our analysis shows that ICNIRP 2020 itself and, in practice, all its referenced supportive literature stem from a network of co-authors with just 17 researchers at its core, most of them affiliated with ICNIRP and/or the IEEE and with ICNIRP 2020 authors in prominent positions, where those who are not are still closely related.

The overlaps between ICNIRP and the committees authoring the referenced literature reviews have been documented multiple times [4, 19, 20]. However, it was not anticipated that these ties would be so strong, that they include all committees behind the literature reviews, as well as the authorships of all the peer reviewed papers used to underpin ICNIRP 2020. Indeed, we would never have expected to find as few as 17 key authors as the smallest set of authors involved in all the literature used to underpin the ICNIRP 2020, and that they constitute a network heavily overlapping with the ICNIRP 2020 authors themselves. It was also not anticipated that the ICNIRP 2020 authors themselves would be represented in all committees. This means that the authors of ICNIRP 2020 are exclusively referring to themselves and their fellow network members as the basis for their own scientifically highly controversial recommendations.

As well, it was highly unexpected to find that the WHO report [11] described in ICNIRP 2020 as "*an in-depth review from the World Health Organization on radiofrequency EMF exposure and health*" [2 p. 486] and presented in these words: "*This independent review is the most comprehensive and thorough appraisal of the adverse effects of*

radiofrequency EMFs on health" [2 p. 517], is in fact a retracted draft where five out of six WHO core group members were ICNIRP affiliates, of whom three are among the authors of ICNIRP 2020. Such a claim and circularity of authorship is encroaching upon something very similar to fraud.

From our findings we draw the conclusion that the referenced literature used in ICNIRP 2020 to underpin its guidelines is neither varied, nor independent or balanced, and is by no means "*consistent with current scientific knowledge*", as claimed by ICNIRP 2020 [2 p. 484]. ICNIRP 2020 bases this claim within this small network only, a claim that runs contrary to the majority of biology-oriented researchers and publications within this research field. Hence, our review shows that the ICNIRP 2020 guidelines fail to meet fundamental scientific quality requirements as to being built on a broad, solid and established knowledge base, uphold a view contrary to well established knowledge within the field, and therefore cannot offer a basis for good governance when setting RF exposure limits for the protection of human health.

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Informed consent: Not applicable.
Ethical approval: The conducted research is not related to either human or animals use.

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