AUDIT
KNOWLEDGE FIELD RADIATION

NATIONAL INSTITUTE FOR PUBLIC HEALTH AND THE ENVIRONMENT (RIVM)

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REPORT ON THE AUDIT OF THE KNOWLEDGE FIELD ON RADIATION AT RIVM

1. FOREWORD BY COMMITTEE CHAIR

This report is the result of intensive consultations between the members of the audit team, members of the scientific staff and the management of RIVM, and representatives of the stakeholders. The report addressed two key questions:

1. Does the output of RIVM in the past six years demonstrate knowledge and competence, and an authoritative execution of the scientific tasks for government and society?
2. Strategic positioning: Do the tasks and the position of RIVM in the knowledge field of radiation match the current and expected future role of RIVM?

The support of the project team of RIVM before and during the preparation and conduct of the site visit was extremely helpful, and we are very thankful for it. The discussions were very open and constructive.

It took some time to better understand the various roles of RIVM, which are broader than research alone: RIVM plays a role in policy advice, information provision, monitoring and surveillance, crisis management, and programme coordination, with pure scientific research being a smaller part of its activities regarding radiation. What we consider essential for both the assessment of the current situation and the future development of the knowledge field is: all of the work of RIVM is science-based, and the advice provided by RIVM requires a solid foundation in the relevant scientific areas. The allocation of personnel and financial resources for basic research is limited, and we encourage the management of RIVM to maintain the current support for basic research as an absolute minimum.

The overall rating of the four areas to be addressed included both the research activities and the scientific work performed to provide state of the art advice.

Prof. Wolfgang Weiss, Chair of the Committee
September 2019

2. THE AUDIT COMMITTEE AND THE PROCEDURES

2.1. Scope of the audit

The audit committee was asked by the Scientific Advisory Board of RIVM to perform an audit of the knowledge field of radiation at RIVM. This audit is based on the Evaluation Guide, "External evaluations at the Dutch National Institute for Public Health and the Environment", which is in turn based on the Standard Evaluation Protocol 2015-2021 (SEP, amended version September 2016) for research reviews in the Netherlands.

The Scientific Board of RIVM used the Evaluation Guide to compose the Terms of Reference for the assessment. The committee was asked to assess the research quality, operational quality, relevance to society, and viability of the knowledge field of radiation, as well as the strategic targets and the extent to which the unit is equipped to achieve these targets. A qualitative review of integrity also formed part of the committee's assignment.

2.2. Composition of the committee

The composition of the committee was as follows:

- Prof. Wolfgang Weiss (chair); retired physicist (former employer: BfS – responsibilities: IR, UV, EMF); current professional priorities: member of the scientific advisory board of the German Government (SSK), Senior Technical Adviser to UNSCEAR (Fukushima update report), Chair of the Scientific Planning Committee for IRPA 15 (Seoul 2020).
- Prof.. Maria Feychting; Professor of Epidemiology at Karolinska Institutet, Institute of Environmental Medicine (IMM), Head of the Unit of Epidemiology at IMM. Research on health effects of non-ionizing radiation, cancer epidemiology. Member of the WHO core group for development of the Environmental Criteria monograph for health risk assessment of radiofrequency electromagnetic fields. Vice Chairman of the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Invited expert in several national and international health risk assessment expert groups on non-ionizing radiation.
- Dr. Johan Camps; PhD in Physics, Unit Head Crisis Management and Decision support unit at the Belgian Nuclear Research Centre, Research in Atmospheric Dispersion Modelling, Radiological Monitoring and the combination of both. Radiological expert in context of the Belgian Nuclear Emergency Plan, President of the R&D Committee of the European Platform for Nuclear and Radiological Emergency Preparedness, Response and Recovery (NERIS), guest professor lecturing in Nuclear Physics at Hasselt University.
- Prof. Michael Siegrist; full professor for consumer behaviour at ETH Zurich. Member of the Scientific Committee of the German Federal Institute for Risk Assessment (BfR), Berlin, the Ethical Commission of the Canton of Zurich, the Scientific Advisory Board of EUFIC, Brussels, the External Science Advisory Panel of Cefic, Brussels, and area Editor of Risk Analysis, and Executive Editor of Appetite.

Peter Hildering, MSc, acted as secretary on behalf of QANU, the independent evaluation bureau hired to support this assessment.

2.3. Independence

All members of the committee signed a statement of independence to ensure that they would assess the quality of the knowledge field of radiation at RIVM (IR, UV, EMF) in an unbiased and independent way. Any existing personal or professional relationships between committee members and the research unit(s) under review were reported. The committee concluded that there were no unacceptable relations or dependencies and that there was no specific risk in terms of bias or undue influence.

2.4. Data provided to the committee

The committee received the self-assessment report and a stakeholder assessment from the knowledge field under review, including all the information required by the Terms of Reference.

The committee also received the following documents:
- the Terms of Reference;
- the SEP 2015-2021, amended version September 2016;
- appendices to the self-assessment and stakeholder assessment;
- a short list of attention points provided by some of the groups interviewed.

2.5. Procedures followed by the committee

The committee proceeded according to the Terms of Reference provided by RIVM. Prior to the first meeting, all committee members independently formulated their preliminary findings of the unit under review and additional questions for clarification based on the written information that was provided prior to the site visit.

The final report is based on the documentation provided by the knowledge field, and also includes the information gathered during the interviews with representatives and stakeholders of that knowledge field at RIVM. The interviews took place on 9-11 September 2019 at RIVM. For more information about the programme, see Appendix 2. Preceding the interviews, the committee was briefed by QANU about research reviews according to the SEP. It also discussed the preliminary findings and questions, decided upon a number of comments and questions, and agreed upon procedural matters and aspects of the review. After the interviews, the committee discussed its findings and comments, allowing the chair to present the preliminary findings orally at the end of the site visit, and the chair and secretary to draft a first version of the review report.

The draft report was presented to the knowledge field concerned for factual corrections and comments. In close consultation with the chair and other committee members, the comments were reviewed by the secretary and incorporated in the final report. The final report was presented to the Scientific Advisory Board of RIVM.

2.6. Application of the framework

The committee used the criteria and categories of the Terms of Reference, based on the Standard Evaluation Protocol 2015-2021 (SEP). For more information on the scores, see Appendix 1. The committee decided to deviate from the format of the assessment report described in the Terms of Reference by not including chapter III on comparing the self-assessment, stakeholder assessment and committee assessment. It considers the self-assessment and stakeholder assessment as input for its own assessment, and incorporated any comparison between the three within the discussion of the criteria.

The committee thinks that the SEP protocol is not ideal for this type of assessment. The protocol is designed to assess academic research, whereas only a fraction of the work of RIVM can be considered academic research according to the accepted definition. Moreover, as the scientific work of RIVM is heavily influenced by its societal tasks and commissioned assignments, it was not considered appropriate to assess one without the other. The committee therefore aimed to evaluate the research within the field of radiation in connection to all other work performed within the field of radiation.

The committee also considered that the knowledge field of radiation is hard to assess with a protocol that takes strategy and targets as its starting point, as the strategic and organizational responsibilities are spread over multiple centres and departments. It therefore recommends that

RIVM consider a better alignment of an assessment with the underlying organizational structure for future reviews.

3. QUANTITATIVE AND QUALITATIVE ASSESSMENT OF THE KNOWLEDGE FIELD ON RADIATION AT RIVM

3.1. Strategy, targets and organization

About RIVM
RIVM has been safeguarding and promoting public health and environmental quality in the Netherlands for over a century. It began in 1909 with a small group of researchers fighting cholera and other life-threatening diseases. It has expanded to become a knowledge institute at the centre of Dutch society, advising on health and the environment. In its role as trusted advisor, RIVM provides the Dutch government with impartial advice on infectious diseases, vaccination programmes, population screening, lifestyle, nutrition, pharmaceuticals, the environment, sustainability, safety and security. It carries out research, provides advice and recommendations, and directs and implements prevention and control responses. The work of RIVM is primarily commissioned by Dutch ministries and inspectorates, and projects are also undertaken within international frameworks, such as those of the European Union and the United Nations. RIVM has many national and international partners, and efforts are always being made to continue to establish new networks in multidisciplinary cooperation at the European and international levels. This is considered essential for the maintenance of competence in the future because the academic activities in the field of radiation have been reduced during the last decades, and it is becoming more and more difficult to recruit trained experts.

RIVM is a leading institute in knowledge and expertise on the relationship between the environment and health. It monitors the quality of air, water and soil, and assesses the risks to health and the environment. In the event of an accident or natural disaster, RIVM measures and monitors the release of substances that may pose a threat to human health and the environment. For more than 50 years, it has been carrying out research on various sources of radiation, such as radioactive substances, light sources, ultraviolet radiation, high voltage power lines, and mobile phones.

In addition, RIVM responds to new environmental issues and new issues posed by society, for instance, the risks of pharmaceutical residues in wastewater and whether there are health risks associated with nanotechnology. It supports the transition to a sustainable and green economy so that future generations can live in a healthy environment. Air pollution, dispersal of toxic substances and risks as a result of large-scale accidents or disasters do not halt at national borders, and thus policy is set in a European framework. RIVM participates in many international networks.

About the knowledge field of radiation
Knowledge of radiation at RIVM is the responsibility of the director of Environment and Safety, who is a member of the Board of Directors of RIVM. Knowledge of radiation covers three main areas:

- Ionizing radiation (IR)
- Ultraviolet radiation (UV)
- Electromagnetic fields (EMF)

This knowledge field has 55 employees, spread over two centres. The knowledge areas IR and UV are located in the Centre for Environmental Safety and Security (VLH), which focusses more on risk and safety, while the research on electromagnetic fields (EMF) is done at the Centre for Sustainability, Environment and Health (DMG), which has more expertise on perceived risk. Another reason for dispersion of the three research lines between two centres is the difference in type of health effects: ionizing and ultraviolet radiation have been proven to be carcinogenic, while electromagnetic fields are not. For a full overview of the organizational structure of RIVM, please refer to https://www.rivm.nl/en/about-rivm/organisation.

Most of the employees in the knowledge field of radiation have a background in the natural sciences: physics (40%), chemistry (25%), biology (11%) and other sciences (18%). Half of them hold a PhD, 21% a master's degree and 27% a bachelor's degree. Appendix 3 includes further quantitative data on the staff associated with the field.

The knowledge field of radiation defines five main activities: research, policy advice, information provision, monitoring and surveillance, and crisis and incident management.

- *Research* is broadly defined as any activity to increase knowledge and expertise on the impacts of radiation or to use this knowledge to devise new applications. The RIVM knowledge field of radiation conducts its own scientific research or acquires results from conferences, workshops and training courses, but also from collaborations with specialist networks.
- *Policy advice* involves advising policy makers on how to make evidence-based or evidence-informed policy. Underpinning surveillance and enforcement is also a part of this task. Many of the national tasks are performed within frameworks of the European Union or other international agreements. Advice on implementation or inspection issues is also part of policy advice. In addition, the RIVM knowledge field of radiation represents the Netherlands in various international networks.
- *Information provision* is an important task of RIVM in order to fulfil its role as a trusted advisor to society at large. The RIVM knowledge field of radiation provides information on all three knowledge areas.
- *Monitoring and surveillance* involve RIVM's task to continuously monitor the level of radiation in the Netherlands by operating the national measurement network for radioactivity. The main task is to detect radiological incidents promptly and to determine their development. Under normal circumstances, the national measurement network for radioactivity gives insight into the level of natural background radiation. In addition, RIVM monitors the solar UV irradiance and notifies the public when exceptional levels of solar UV irradiance are expected or measured. The knowledge area of EMF monitors scientific and technical developments, as a precaution.
- *Crisis and incident management* relates to RIVM's role in the national response to emergencies following nuclear or radiological accidents and incidents. It hosts and takes part in the network of expertise on radiation and health (RGEN). The RGEN reports and advises administrators and decision makers on the radiological effects (expected) during an emergency and countermeasures before, during and in the aftermath of an emergency.

Strategy and targets

Due to the nature of the institute as an independent advisor of government and society, most of RIVM's activities are based on the questions posed by its commissioning clients. To maintain expertise and develop new knowledge to undertake these activities, RIVM allocates internal research funds to its priority areas. These priority areas are described in the Road Map RIVM 2020, the Institute's strategy for 2013-2020. There are broad themes such as health economics, risk communication, healthy urban living, and safe, healthy and sustainable food, which span the various centres of RIVM. Experts at RIVM can apply for internal research funds through internal competition.

The committee notes that there is no dedicated strategic plan at the level of the knowledge field of radiation. The Road Map RIVM 2020 is translated into strategies for the various centres, but they have a much wider scope than the individual knowledge areas. The priority areas defined in the Road Map do not have a natural fit with the field of radiation, making it difficult for the field to develop a strategy in relation to these areas.

According to the Committee, the lack of a strategic plan for the field of radiation limits the field in the formulation of its own research priorities and allocation of the associated resources and funding. It recommends developing and implementing a detailed strategic plan covering the entire knowledge field and the associated sub-fields (IR, EMF and UV). This plan should include what the field wants to achieve and what resources are needed to realize this, and should be formalized and regularly evaluated. Alternatively, RIVM could consider expanding the scope of its priority areas to include the

knowledge field of radiation, so the field can tie its strategy to the institute-wide research strategy. These two options are further explored in the discussion under the Viability criterion.

For the remainder of this report, the committee considers the five main activities defined in the previous section as the strategy on which to base its assessment.

3.2. Research quality

To assess the research quality within the field of radiation, the committee considered the scientific output and the expertise of the researchers involved. It concluded that several of the institute's experts are considered an authority in the field of radiation. They are involved in high-level international networks such as the International Atomic Energy Agency (IAEA), the United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR), the World Health Organization (WHO) and in European-funded research projects.

A quantitative overview of the scientific output of RIVM is provided in appendix 3. The committee considers that this output shows that good science is being done, with competence in core topics in the radiation field. Examples include peer-reviewed publications on radon in dwellings, the formation of vitamin D3 through UV radiation, dose-assessment methodology for radiological surface contamination, and the development of exposure assessment methods for RF-EMF. It also demonstrates that the output is limited in quantity (on average 10 peer-reviewed articles per year in recent years). The committee discussed this aspect with the radiation experts: scientific publications at RIVM are considered important, but in terms of funding and resources, such publications are rather a side activity compared to the much larger commissioned assignments and reports. It also understood that the rise in quantity (roughly doubled in recent years compared to 5 years ago) was realized without additional funding. Given this explanation, it became more impressed by the scientific output generated with the limited resources allocated to this work.

The committee understands that the experts at RIVM are not full-time researchers and therefore should not be considered in the same way as their colleagues at universities when judging the quality and quantity of their scientific research. The majority of their work is related to science-based projects rather than scientific research. The committee thinks this is understandable in the context of RIVM's mission. Considering the commissioned work in the knowledge field, it could confirm that this is in fact science-based work. The commissioned research performed by the experts is based on up-to-date knowledge and insights within the field. The experts can make use of state-of-the-art facilities such as radionuclide laboratories and high-quality monitoring networks for radioactivity and UV. The policy advice and the information provided are based on state-of-the-art scientific knowledge.

The committee therefore concludes that the quality of the knowledge field of radiation at RIVM is *very good*. It commends RIVM for paying attention to and appreciating the scientific activities of its experts and recommends, if possible, providing additional funding and incentives. It thinks it is important for experts in the field performing science-based work to remain connected to the relevant scientific developments. Topics such as atmospheric transport modelling (ATM), a field which is undergoing rapid development, are essential for the models RIVM uses for the dispersion of radioactivity, and therefore directly influences the operational quality of RIVM. Similarly, the introduction of the fifth-generation network for wireless communication puts new demands on exposure assessment methodology. The experts should therefore remain actively involved in the field through participation in the scientific community.

During the discussions with the experts and the stakeholders, future research needs were identified. Examples include radioactive waste, cosmetic applications of EMF, the new 5G standard and medical application of IR. It became evident that additional social science expertise in the areas of risk perception and risk communication are needed in order to address many of the pertinent questions.

With regard to the entire field, the committee sees opportunities for further cooperation between the natural and social sciences. RIVM has recently turned to hiring more researchers with expertise in the social sciences, such as risk communication and behavioural sciences. The committee fully supports this development. It thinks that many of the topics in the radiation field are strongly associated with risk perception rather than with quantitative risks, either resulting in overestimation (IR and EMF) or underestimation (UV) of risks by the general public. It believes that the insights from the behavioural sciences will prove to be instrumental in information provision for public awareness. In the discussion with the various groups, it discovered that there are different views on this topic within the organization, and that some experts are not convinced of the necessity for such a cooperation. It therefore recommends that the management of the departments involved take structural measures and provide incentives to integrate the social sciences viewpoint in all areas of expertise of RIVM. It also strongly recommends placing social scientists in units together with natural scientists and not creating isolated social science units within RIVM.

3.3 Operational quality

To assess the operational quality of the knowledge field of radiation, the committee studied the documents supplied, interviewed the experts and stakeholders of RIVM, and visited the facilities related to the performance of the five tasks of the knowledge field as defined in section 3.1. It considered the operational quality for the various areas of expertise: ionizing radiation (IR), ultraviolet radiation (UV), electromagnetic field radiation (EMF), and medical and occupational exposure, which contains elements from both IR and EMF.

Overall, the committee considers the operational quality of the knowledge field of radiation to be *very good*, and it considers some aspects of the institute's work in all three knowledge areas to be excellent. This includes the IR laboratories and emergency response, as well as the work of some of the experts in non-ionizing radiation. There are, however, subtle differences in detail if the individual areas of expertise are analysed.

Ionizing radiation (IR)
The knowledge area of ionizing radiation (IR) is involved in the monitoring and surveillance of the level of radiation within the Netherlands, and crisis and incident management for nuclear or radiological accidents and incidents. It is closely involved in policy development for health and safety with regard to ionizing radiation, and represents the Netherlands in various international networks. It also informs the general public about the risks of ionizing radiation, such as exposure to radon and thoron in dwellings and workplaces. RIVM has excellent facilities at its disposal for performing these tasks. The committee had the opportunity to visit the crisis centre that the institute has prepared in case of a nuclear incident, as well as the emergency vehicles that can be used as mobile laboratories for performing measurements in contaminated areas. The committee was impressed by these state-of-the-art facilities and the excellent work within this area of expertise.

During the site visit, the committee discussed various ideas to further improve and fine-tune the emergency preparedness:

- The knowledge area is considering using the mobile laboratories for doing regular measurements in the field. This will provide the operators and experts with extra opportunities to practise with the equipment. The committee fully supports this idea.
- The operational responsibilities in the case of a large-scale nuclear emergency could be further clarified. This applies in particular to emergency crisis communication. The knowledge area could consider training a number of experts as spokespersons and/or (social) media responders in crisis situations. Answers to predictable questions could be formulated and kept ready for use. According to the committee, this would improve the effectiveness of crisis communication in the case of a major accident.
- The emergency preparation plans at RIVM currently focus on the immediate aftermath of a nuclear incident. The committee recommends extending this to the transition and recovery phase, including plans for cleaning up the radioactive waste and dealing with the

contaminated area. This was found to be an important part of the developments after, for instance, the Chernobyl and Fukushima disasters, and it would be wise to consider it as part of the national emergency preparedness plan.

- As discussed in section 3.2, the knowledge area should strive to keep its knowledge on the scientific developments in the field of atmospheric transport modelling (ATM) up-to-date, as this plays a major role in the models the experts use to forecast the spread of contamination due to nuclear incidents.
- The radionuclide laboratory could investigate the measurement of currently unavailable radionuclides and/or difficult to measure radionuclides related to, for example, decommissioning. In this context C-14 in concrete was mentioned.

Ultraviolet radiation (UV)

The knowledge area of UV mainly focuses on monitoring and information provision with regard to UV radiation. Being originally launched to monitor ozone layer depletion, it has now moved on to the health effects of UV radiation and the associated risks of skin cancer. It maintains a UV measuring station and publishes its measurements and forecasts on a website. In the case of expected exceptional levels of solar UV irradiance, it notifies the public. The institute has an active risk communication strategy with regard to UV radiation, aiming to influence the public's behaviour with regard to exposure to sunlight in order to reduce the incidence of skin cancer and cataracts.

The committee visited the UV measuring station at RIVM and was impressed by the solid measurements the field has been performing for the past years. It understood that the equipment is likely to be modernised and moved to the new RIVM building. It recognises the importance of this work and endorses this. It was impressed by the active risk communication towards the public with regard to exposure to sunlight (see also Section 3.4). In line with this goal, it recommends further research into the behavioural mechanisms behind sunlight exposure. By discovering why people expose themselves to unhealthy amounts of UV radiation and what narratives could influence this behaviour, the knowledge area could further improve its risk communication strategies.

Electromagnetic Fields (EMF)

The operational tasks of RIVM with regard to EMF consist of investigating the possible detrimental effects to human health due to exposure to electromagnetic fields (esp. prolonged), for instance from high-voltage power lines, underground cables, electronic devices and mobile communication networks. RIVM informs the public by acting as independent expert in information meetings organized by the government, maintaining the public grid map ('netkaart') of the Netherlands, and answering direct questions from the public, also as part of the Dutch 'Kennisplatform EMV'. The committee concludes that the operational quality in the field of EMF is very good and performed by a group of competent experts. The size of the current group of experts is relatively small. Due to the uncertainty of funding of this knowledge area by commissioning clients, the committee considers the sustainability of the knowledge area of EMF at risk. This will be further discussed in Section 3.5. This is more urgent considering the fact that the committee foresees a societal need for EMF expertise in relation to the adoption of the 5G mobile communication networks. The perceived health effects of 5G are already being brought to the societal agenda by activists and protestors. The committee recommends that the knowledge area increase its focus on 5G networks and make sure that it is equipped to deal with this topic in the near future.

Medical and occupational exposure

It became obvious from the discussions with the experts and stakeholders that there is no clearly defined, independent role of RIVM in this area. RIVM usually gets assignments from the Ministry of Health to perform desk research or acquire updated information regarding the safe use of radiation from the field using questionnaires. The experts focusing on medical and occupational exposure to radiation monitor and advise on the doses involved in the medical and occupational setting. This includes both ionizing (X-ray, CT, radiotherapy) and non-ionizing (lasers, high-voltage construction work) radiation, and both IR and EMF experts. RIVM is not equipped to execute more clinical or practice-oriented radiation research, but it maintains close connections with InHolland, a university

of applied sciences, in particular with the department training radiographers, medical nuclear workers and radiation therapists, commonly referred to in Dutch by *medisch beeldvormings- en bestralingsdeskundige* (MBBs).

Based on interviews with experts and stakeholders, the committee concludes that the role of RIVM towards medical exposure in particular is less clear-cut than in the other areas of expertise. The knowledge area collects and disseminates information on the use of medical radiation, but relies on the cooperation of hospitals, which do not always share detailed information on the doses administered to patients. The committee recommends that RIVM take a stronger position with regard to this issue. Medical exposure is known to be the largest contributor to radioactivity dose for most individuals due to the increase in diagnostics, as well as exposure to electromagnetic fields, such as medical and cosmetic laser treatments. The committee considers that there should be an authority that has full access to the available data, not only the estimates that are currently provided by hospitals to RIVM. It recommends maintaining closer connections with MBBs, medical physics experts and medical doctors, and seeking to perform projects together with them.

The result of a strategic discussion of the roles and responsibilities in this important field should be a clear distribution of responsibilities towards monitoring and interpretation of results of medical exposure to radiation, either by RIVM, the field of medical physics itself, or a transparent cooperation between the two. The committee also recommends increasing the attention paid to exposure to non-ionizing radiation in medical settings and for cosmetic purposes, and implement this in its monitoring and advisory role.

Finally, there are open scientific questions to be answered, such as the risks of repeated diagnostic applications or the Normal Tissue Complication Probability (NTCP), for example in relation to proton therapy. Given the current staffing and the uncertainties on the allocation of responsibilities, RIVM is not in a position to contribute to these open scientific questions.

3.4. Relevance to society

Due to RIVM's mission as an independent expert organisation for the government and the general public, the work of the knowledge field of radiation at RIVM is societally relevant by nature. Most commissioned assignments are directly related to societally relevant topics such as the monitoring and surveillance of radiation, investigating risks of various types of radiation, and emergency preparations for calamities. The stakeholders interviewed, which all also had a role as commissioning client, were satisfied with the role of RIVM and considered the field a reliable partner.

The committee noted that the role of RIVM in communications to the general public differs greatly from one knowledge area to another. For instance, the knowledge area of UV is very active in communicating to the general public, with the aim to directly influence their behaviour in regard to sunlight exposure, appearing as experts in the media, for instance during the 2019 heatwave. On the other hand, the knowledge area of EMF prefers to maintain a neutral stance, acting solely as an information provider, e.g. through commissioned public meetings or the Kennisplatform EMV. For IR, the majority of communication is done by the ANVS, the Dutch Authority for Nuclear Safety and Radiation Protection. The committee can understand all of these positions in relation to the field, but recommends making these choices more explicit in the strategic plan mentioned in section 3.1. By defining its roles (actual and perceived) and responsibilities in risk communication towards a larger audience, the field can better manage the expectations of its commissioning clients. For instance, some stakeholders within the area of EMF indicated that they would like the institute to take a firmer stance in communicating with the general public. According to the committee, elaborating on the communication strategy in the various areas could make the position of RIVM in these discussions more transparent. In general, the committee considers that communication by experts is to be preferred, and recommends using the experts within the various areas as spokespersons towards the general public wherever possible. Providing media training for several of its experts, as the field has already done in some cases, is considered by the committee to be a good practice.

The committee considers the societal relevance of the field to be *very good*. The field is well-aligned with the needs of society and the government due to its nature, and fulfils this role in a reliable and independent way.

3.5. Viability

The committee discussed the viability of the research and operations performed at RIVM with various delegations throughout the interviews. As mentioned above, it considers the work of the knowledge field of radiation at RIVM to be at a high level, but there is a need for more structural strategic planning to be able to maintain this high level. As the field of radiation is underrepresented in the general strategy of RIVM and does not have its own strategic plan, it lacks a long-term vision on what it considers its core expertise, and what is needed to maintain this in terms of staffing and resources. Furthermore, the field is spread over multiple centres and departments, and as a result does not have a clear identity within RIVM.

The committee recommends that the institute develop a strategic plan for the knowledge field of radiation, detailing the priorities, the required expertise, and the associated resources and funding needed to maintain this. This could be tied into the institute-wide strategic plan or be drawn up as a separate strategic plan for the field. Developing this plan should include extensive consultation inside and outside RIVM in order to map all relevant developments and viewpoints with regard to the field. It should also identify single points of knowledge and other sub-critical areas within the expertise of RIVM, and include measures to safeguard the expertise within these areas if it is deemed essential for the field. This plan should subsequently be approved and committed to by the management of RIVM, including the described priorities and associated resources.

In some areas, the lack of strategic planning is an urgent issue, as not all topics are widely accepted by the commissioning clients. The knowledge area of EMF is in danger of losing project funding due to the government's reduced interest in the topic. Being a small area within RIVM, it is at risk of losing expertise in this topic. This is even more relevant as the committee foresees a renewed relevance for the field, for instance due to the introduction of 5G. It recommends that RIVM invest in order to maintain the existing expertise as an absolute minimum, as it would take RIVM years to rebuild any loss of critical mass in the case of EMF experts leaving or retiring from the Institute.

In another sense this is also the case for ionizing radiation protection. There are currently no universities in the Netherlands investing in this topic, which makes RIVM the scientific authority in this field. Maintaining and developing expertise within this area requires a minimum of basic funding with which the field can maintain its level of scientific quality by participating in the international scientific community and training the next generation of radiation experts. According to the committee, this is a shared responsibility of both RIVM and its external partners (government, nuclear industry, medical field). RIVM should try to persuade the partners to invest in maintaining expertise in radiation protection within the Netherlands. For instance, ANVS initiated a study on a national nuclear knowledge management programme to guarantee knowledge preservation and transfer. The IR experts of RIVM could play an important role in such a programme. The field should also consider increasing its cooperation with international partners, such as universities in other European countries working on research in radiation topics.

A last recommendation of the committee concerns the internal appreciation of the work of its experts. Other than researchers working in academia, the research results of the experts at RIVM often do not result in public, peer-reviewed papers, but in internal, sometimes confidential reports. This could cause experts to feel that their work is not credited, and does not lead to their recognition as researchers by peers in universities. The committee saw some signs of this in the interviews. It recommends that the management of the institute consider initiatives to give its experts credit for their work internally. Such an appraisal of their work could add to its visibility, and as a result support their motivation.

The committee considers the overall viability of the knowledge field to be *very good*. The field has the expertise needed to realize its research and operational quality, and is sufficiently funded through RIVM and its commissioning clients in order to be able to perform their work. However, it is in danger of dropping to a lower level of viability due to limited strategic planning and a small basis in some fields of expertise. The committee recommends developing a strategic plan over the full width of the field to counter this.

3.6. Integrity

RIVM aims to be a trusted advisor for the government and society. As an independent institute that relies heavily on its commissioning clients, it must balance between the proximity of policy makers and independence in the execution of its research.

The committee read the stakeholder assessment and discussed the perceived integrity of the knowledge field of radiation with both the experts at the Institute and its stakeholders. It concludes that the experts are seen by their stakeholders as being independent and having integrity in performing their research. Although the commissioning clients determine the research question (the why and the what), the experts themselves are in charge of how the research question is answered. This separation of responsibilities is explicitly laid down in the RIVM Act (1997).

The interviews with stakeholders confirmed that this separation is strictly adhered to, and that commissioning clients have no say in the research methods or outcomes of the research questions they pose. The committee found no indications of conflicts of interest between RIVM experts and the government, and therefore judges positively on the knowledge field's integrity.

3.7. Conclusion

Overview of the quantitative assessment

Research quality:	very good
Operational quality:	very good
Societal relevance:	very good
Viability:	very good

4. RECOMMENDATIONS

1. Develop a strategic plan for the knowledge field of radiation. This could either be tied to the institute-wide strategic plan or be drawn up as a separate strategic plan for the field of radiation. This plan should:
    a. detail the priorities, the required expertise, and the associated resources and funding needed to maintain this;
    b. include the result of extensive consultations inside and outside RIVM in order to map all relevant developments and viewpoints with regard to the field;
    c. identify single points of knowledge and other sub-critical areas of expertise, and include measures to safeguard this expertise if it is deemed essential for the field;
    d. include initiatives focussing on the long-term recruitment and training of experts with the aim to minimize the risk of losing competence in key areas;
    e. be approved and committed to by the management of RIVM, including the described priorities and associated resources.

2. Keep paying attention to and appreciating the scientific activities of the experts, so that they can remain actively involved in the field through participation in the scientific community.

3. Take structural measures, provide incentives and create a culture of interdisciplinary research that helps to integrate the social sciences viewpoint in all areas of expertise of RIVM.

4. Broaden the expertise of the units by including social scientists from the fields of risk perception and risk communication. In order to facilitate interactions with natural scientists, these social scientists should not be placed in a separate social science unit.

5. Further clarify the operational responsibilities in the case of a large-scale nuclear emergency, in particular with regard to emergency crisis communication.

6. Extend emergency preparation to the transition and recovery phase of a nuclear incident, including plans for cleaning up the radioactive waste and dealing with the contaminated area.

7. Keep up-to-date on the scientific development in the field of atmospheric transport modelling (ATM), as this plays a major role in the models the experts use to forecast the spread of contamination due to nuclear incidents.

8. Perform further research into the behavioural mechanisms behind sunlight exposure in order to improve the risk communication strategy.

9. Increase the focus on possible health effects of 5G networks and associated exposure assessment challenges, and make sure the critical mass of expertise in the field of EMF is maintained.

10. Take up the discussion on the monitoring of medical exposure together with the medical physicists at the hospitals, aiming at a clear distribution of responsibilities towards monitoring of medical exposure to radiation, either by RIVM, the field of medical physics itself, or a transparent cooperation between the two.

11. Better define its actual and perceived roles and responsibilities in risk communication towards a larger audience in the various fields of expertise.

12. Use experts within the various areas as spokespersons towards the general public wherever possible, and providing media training where necessary.

13. Increase attention to exposure to non-ionizing radiation for medical and cosmetic purposes, and implement this in its monitoring and advisory role.

14. Try to persuade the right partners to invest in maintaining expertise in radiation protection within the Netherlands, as well as increasing cooperation with international partners.

15. Consider initiatives of giving its experts credit for their work internally.

APPENDICES

APPENDIX 1: THE CRITERIA AND CATEGORIES

The assessment consists of five criteria. Criteria A to D are to be assessed both quantitatively and qualitatively, criterion E is only assessed qualitatively.

A. Research quality
The committee assesses the quality and the contribution of the research to the body of scientific knowledge and applications. The committee also assesses the quantity of the research results such as scientific publications, contributions to methodology, instruments and software tools developed by the knowledge field, and other contributions to science.

B. Operational quality
The committee assesses the quality of the execution of the tasks of the RIVM knowledge field, but also to what extent the knowledge field achieves its goals aimed at making choices by society to obtain healthier individuals and a healthier environment. This includes the reports and other products (websites, maps, information markets) developed by the knowledge field. For instance, the knowledge field measures a Solar-UV index according to fixed and scientific sound procedures. A higher goal is creating awareness among sunbathing individuals and affecting their behaviour in order to prevent skin cancers.

C. Relevance to society
The committee assesses the quality, quantity and relevance of, for instance:

- Contributions targeting specific economic, social or cultural target groups
- Publications and advisory reports for policy
- References in letters to parliament
- Contributions to public debates, second opinions

In addition, this criterion includes the quality of knowledge transfer and the societal impact and use of the output of the research unit. The way the interest of stakeholders is taken into account is also part of relevance to society.

D. Viability
The committee assesses the strategy that the knowledge field intends to pursue in the years ahead and the extent to which it is capable of meeting its targets in research and society.

E. Integrity
The committee assesses the knowledge field's policy on research integrity and conflicts of interest and the way violations thereof are prevented. The committee is interested in how the knowledge field deals with research data, data management and data integrity, and in the extent to which an independent and critical pursuit of science is made possible within the knowledge field.

Categories A to D can be scored as follows:

Category	Meaning	Research quality	Operational quality	Relevance to society	Viability
1	Excellent / world leading	The knowledge field[1] has been shown to be one of the most influential research groups in the world in its particular field	The executed operations are of outstanding quality and are highly effective	The knowledge field makes an outstanding contribution to society	The knowledge field is excellently equipped for the future
2	Very good	The knowledge field conducts very good, internationally recognized research	The executed operations are of very good quality and are very effective	The knowledge field makes a very good contribution to society	The knowledge field is very well equipped for the future
3	Good	The knowledge field conducts good research	The executed operations are of good quality and are effective	The knowledge field makes a good contribution to society	The knowledge field makes responsible strategic decisions and is therefore well equipped for the future
4	Unsatisfactory	The knowledge field does not achieve satisfactory results in its field	The executed operations are of unsatisfactory quality and have insufficient effect	The knowledge field does not make a satisfactory contribution to society	The knowledge field is not adequately equipped for the future

[1] Please note that in the Terms of Reference the term *research field on radiation* was used. In the self-assessment, however, RIVM indicated that *knowledge field on radiation* is a more appropriate term, as RIVM is primarily a knowledge institute.

APPENDIX 2: PROGRAMME OF THE SITE VISIT

Monday, September 9th, 2019

Start	End	Activity
08.45	09.00	Welcome - programme of the day
09.00	12.00	Preliminary meeting committee: instruction and discussion
12.00	12.30	Welcome by Director Environment and Safety and RIVM Scientific Advisory Board
12.30	13.30	Lunch
13.30	15.00	Interview Experts Ionizing Radiation (Research science/policy driven; Monitoring/ measurement; Emergency Response)
15.00	15.10	Break
15.10	16.20	Interview Experts Non-Ionizing Radiation (UV; EMF)
16.20	16.30	Break
16.30	17.00	Interview Experts Medical and Occupational (IR; EMF)
17.00	18.00	Internal panel discussion

Tuesday September 10th, 2019

Start	End	Activity
08.45	09.00	Welcome - programme of the day
09.00	09.50	Internal panel meeting
09.50	10.20	Interview Top expert/top advisor/CSO's
10.20	10.30	break
10.30	11.00	Interview Programme coordinators (IR, UV, EMF)
11.00	11.10	break
11.10	11.40	Interview stakeholder DG for the Environment and International Affairs (Min. Infrastructure and Water Management)
11.40	11.50	break
11.50	12.20	Interview stakeholder Crisis Management Centre (Min. Infrastructure and Water Management)
12.20	12.40	change of rooms
12.40	13.10	Interview stakeholder Municipal Health Department of Amsterdam and teleconference with Radiocommunications Agency Netherlands
13.10	13.20	break
13.20	14.00	Lunch and presentation crisis room
14.00	15.40	Visits Radionuclide lab, UV measurements, measurement vehicles
15.40	16.20	break
16.20	17.20	Interview with Authority for Nuclear Safety and Radiation Protection
17.20	17.40	break
17.40	18.10	Interview with Department heads (IR, UV, EMF)
18.10	19.00	Completion of report day 2

Wednesday September 11th, 2019

Start	End	Activity
08.45	09.00	Welcome - programme of the day
09.00	09.30	Interview with Director and Centre heads
09.30	10.00	Deliberation
10.00	10.30	Interview stakeholder Netherlands Commission on Radiation Dosimetry
10.30	12.30	Panel deliberation
12.30	13.15	Lunch
13.30	14.00	Closing meeting (final conclusions and recommendations)

APPENDIX 3: QUANTITATIVE DATA

Table 1: Staff capacity (FTE)

Type of staff	2013	2014	2015	2016	2017	2018
Scientific staff[1]	31.6	31.9	36.1	35.4	36	34
Post-docs[2]	0	0	0	0	0	0
PhD students[3]	0	0	0	0	0.6	0.7
Total research staff	**32**	**32.3**	**36.5**	**35.8**	**37**	**35**
Support staff	2	1.9	2.1	2.2	2.2	2.1
Visiting fellows	0	0	0	0	0	0
Total staff	**33.6**	**33.8**	**38.2**	**37.6**	**38.8**	**36.7**

Note 1: Comparable with WOPI categories HGL, UHD and UD; tenured and non-tenured staff
Note 2: Comparable with WOPI category Onderzoeker
Note 3: Standard PhD (employed) and Contract PhDs (externally or internally funded but not employed)

Table 2: Funding

Funding source (k€)	2013	2014	2015	2016	2017	2018
Commissioning clients[1]	6300	6425	7140	7345	7490	7490
Direct funding[2]	395	405	360	225	105	135
Research grants[3]	53	10	0	0	0	0
Contract research[4]	120	95	40	150	145	145
Other[5]	0	0	0	0	0	0
Total funding	**6870**	**6935**	**7545**	**7715**	**7740**	**7770**
Expenditure (k€)						
Personnel costs	4215	4420	5240	5215	5335	5210
Other costs	2345	2520	2320	2340	2295	2350
Total expenditure	**6560**	**6940**	**7560**	**7555**	**7630**	**7565**

Note 1: Government (national, local, provincial, international)
Note 2: Direct funding (basic financing / lump-sum budget, Strategic Research Programme (SPR) of RIVM)
Note 3: Research grants obtained in national scientific competition, e.g. grants from The Netherlands Organization for Scientific Research (NWO) and the Royal Netherlands Academy of Arts and Sciences (KNAW)
Note 4: Research contracts for specific research projects obtained from external organizations, such as industry, government ministries, European organizations and charitable organizations; including the Knowledge Platform on EMF and Health
Note 5: Funds that do not fit into the other categories

Table 3: Output

Output	2013	2014	2015	2016	2017	2018
Refereed articles	4	4	7	13	6	10
Non-refereed articles[1]	3	0	5	4	6	3
Books	0	0	0	0	0	0
Book chapters	0	0	0	0	0	0
PhD theses	0	0	0	0	0	0
MSc theses	0	0	2	1	0	2
Secondary school theses	0	0	0	0	0	1
Conference papers[2]	9	8	13	12	12	17
Professional publications[3]	22	14	27	19	27	27
Publications aimed at the general public[4]	1	2	2	1	7	6
Total publications	**39**	**28**	**56**	**50**	**57**	**66**

Note 1: Articles in journals that are non-refereed, yet deemed important for the field
Note 2: Including oral contributions
Note 3: Publications aimed at professionals, e.g. commissioner clients, including RIVM reports
Note 4: Includes the information meetings and layman's papers