PAPER

Women in radiation (WiR)—a perspective for the strengthening of radiation protection

IOP Publishing J. Radiol. Prot. 42 (2022) 010502 https://doi.org/10.1088/1361-6498/ac2909

Journal of Radiological Protection

PAPER

RECEIVED
8 August 2021

REVISED
9 September 2021

ACCEPTED FOR PUBLICATION
22 September 2021

PUBLISHED
17 January 2022

Women in radiation (WiR)—a perspective for the strengthening of radiation protection

Gabriele Voigt[1], Nicole E Martinez[2], Jacqueline Garnier-Laplace[3], Florence Maher[3], Claire Cousins[4], Gillian Hirth[5], Renate Czarwinski[6], Ruxandra Sapoi[7], Kazuyo Suzuki[8], Rui Qiu[9], Melina Belinco[10] and Marina Di Giorgio[11,*]

[1] WiN Global, 2380 Perchtoldsdorf, Austria
[2] Clemson University, Clemson, SC, United States of America
[3] OECD Nuclear Energy Agency, Boulogne-Billancourt, France
[4] ICRP, Ontario, Canada
[5] UNSCEAR, Vienna, Austria
[6] German-Swiss Radiation Protection Association, Germany
[7] Dositracker, Dositracker, Magurele, Romania
[8] Kyoto University Hospital, Kyoto, Japan
[9] Tsinghua University, Beijing, People's Republic of China
[10] Women in Nuclear Argentina, Buenos Aires, Argentina
[11] Nuclear Regulatory Authority, Buenos Aires, Argentina
[*] Author to whom any correspondence should be addressed.

E-mail: mdigiorgio@arn.gob.ar

Keywords: gender balance, networking, role models, mentoring, radiation protection, international cooperation

Abstract

Gender balance refers to the equitable treatment and access to opportunities for all genders. In order to achieve true gender balance, a variety of proactive approaches developed collaboratively, with insight from multiple perspectives, need to be implemented. With that purpose, the participation of women in professions related to radiation and radiation protection was prioritised and given high visibility by allocating a 'Women in Radiation' (WiR) Special Session at the 15th International Congress of the International Radiation Protection Association (IRPA), hosted by South Korea on 20 January 2021. In this session, various issues related to gender balance and equity/equality were highlighted by the panellists, and further elaborated in a subsequent discussion with attendees. The main goal of the WiR Special Session was to convene women from different organisations, career and age stages, disciplines and countries, in particular to consider the Asian–Oceanic vision and status of gender equality, along with other topics to support a 'Call for Action', with concrete recommendations subsequently provided to IRPA. The discussion stressed the main needs and challenges faced by women working in various radiation fields, along with raising awareness of possible professional and employment opportunities. This paper identifies some steps necessary to encourage, enhance and support the inclusion of more diversity in nuclear professions with specific emphasis on women. In conclusion, gender balance and equality must be at the heart of any strategic plan for the future of the radiological protection profession; international cooperation between relevant bodies is essential for success and could serve as a catalyst for specific policy statements aimed at achieving a balanced representation of women in radiological protection.

1. Introduction

Gender balance can be measured by the ratio of women to men in similar positions within an organisation, and more broadly refers to the equitable treatment and access to opportunities for all genders. Gender balance should be regarded as a crucial metric in Science, Technology, Engineering and Mathematics (STEM), but does not consist of merely setting numerical goals (e.g. the number or percentage of women in

a department). Although it can be valuable to have numerical goals for assessment purposes, the idea of focusing solely on numbers is insufficient as a viable strategy for transparent and equitable hiring and promotion processes or for supporting respectful working environments free from discrimination. In order to achieve true gender balance, a variety of proactive approaches developed collaboratively with insight from multiple perspectives need to be implemented (Suzuki *et al* 2015).

With that in mind, the participation of women in professions related to radiation and radiation protection (RP) was prioritised and given high visibility at the 15th International Congress of the International Radiation Protection Association (IRPA), hosted by South Korea; a dedicated Special Session on Women in Radiation (WiR), organised by Marina Di Giorgio, was held as a live, virtual panel activity on 20 January 2021. Of note is that the promotion of a long-term vision for IRPA to support gender equality was initiated at the last Latin American Congress IRPA CUBA, held in 2018.

In the IRPA15 session, various issues related to gender balance and equity/equality were highlighted by the panellists and further elaborated upon in a subsequent discussion with attendees. It is noteworthy that this session was the first of its kind on gender-related issues included in an IRPA International Congress, notably with the contribution of the main radiation specialised international or regional organisations.

The main goal of the WiR Special Session was to convene women from different organisations, career stages, disciplines and countries, in particular to consider the Asian–Oceanic vision and status of gender equality, along with other topics to support a 'Call for Action', with concrete recommendations subsequently provided to IRPA. The discussion stressed the main needs and challenges faced by women working in various radiation fields, along with raising awareness of possible professional and employment opportunities.

This paper discusses several important considerations for the advancement of WiR sciences, who although historically underrepresented and ignored, have nonetheless made substantial contributions to the field (Martinez 2017). New efforts in encouraging WiR sciences have led to more women entering the specialities and more women serving in prominent leadership roles. Even with these accomplishments, women still face challenges and barriers to success, a situation that we as a community can work together to improve.

In the following, we identify some steps necessary to encourage, enhance and support the inclusion of more diversity in nuclear professions with specific emphasis on women. Success in this regard, along with other elements of diversity and inclusion, would also increase the workforce in this profession.

Presentations made at the Special Session are grouped by theme, with brief introductions of the speakers followed by general summaries of their presentations.

2. Presentations and panel discussions

2.1. Culture and empathy

Although many presentations in this session related to the culture in radiation and nuclear sciences, two covered this topic as their primary focus along with empathy in keeping with the theme of the Congress. These presentations serve to provide background information and set the stage for more specific discussions.

Nicole Martinez presented the importance of considering intersectionality when developing strategies related to diversity and the promotion of women. Dr Martinez is an associate professor at Clemson University in the USA with a joint faculty appointment at Oak Ridge National Laboratory. Prior to that, she served in the US Navy and briefly worked in industry. She is the current Secretary of the Health Physics Society, Vice-Chair of Committee 4 of the ICRP, and a Certified Health Physicist.

Melina Belinco gave a presentation highlighting the male designed and dominated culture in nuclear sciences and technology, and the importance of shifting that culture to be more inclusive. Ms Belinco is the National Liaison Officer to the International Atomic Energy Agency (IAEA) at the National Atomic Energy Commission (CNEA) of Argentina. In 2016, she undertook a special assignment at the IAEA Department of Technical Cooperation in Vienna. After that, she was also recruited as an IAEA expert in capacity-building activities to strengthen the leadership skills of young people and women in the nuclear field. She is also the current Vice-President of Women in Nuclear (WiN) Global.

2.1.1. Diversity and intersectionality.

The concepts of diversity, equity and inclusion are not new (O'Donovan 2018) but have gained more attention and prioritisation within the scientific community over the past several years, including in RP (Gillenwalters and Martinez 2017).

Diversity refers to the multitude of ways, both objective and subjective, that people differentiate from each other. Even within a group of women, there may be differences in age, race, ethnicity, sexual orientation,

religion, career path or stage, caregiver status, level or focus of education, socioeconomic status, health status, etc. Such differences often form a significant part of our identity as individuals; in other words, we place value on our individuality and what makes us ***us*** (O'Donovan 2018). Intersectionality broadly refers to the overlap between the identities we have; these identities together interact to influence our experiences (Muhs *et al* 2012). Initiatives supporting women should be inclusive, ensuring that we focus our conversations and actions to include women who have additional marginalised identities, e.g. women of colour including Indigenous women, women with disabilities, transgender women, etc. This idea is an important consideration as we begin to pursue more equitable interactions, procedures and possibilities for everyone. A more detailed discussion of intersectionality in this context with specific examples as to its importance can be found elsewhere in this issue (Martinez 2021).

Of note is that equity refers generally to fairness and is distinct from equality in that it recognises that different individuals have different needs. Equity is a form of justice, and justice is one of the core ethical values of the system of radiological protection (ICRP 2018). Inclusion or inclusivity in an organisational context refers to how well an organisation and its members engage and connect with people across the spectrum of diversity (Ferdman 2013). An inclusive organisation adopts policies and practices that provide every person connected to the organisation an equitable opportunity to be happy and successful. Developing and maintaining an inclusive organisation is to the benefit of both the organisation and its members (Ferdman 2017). Inclusivity is a foundational procedural ethical value in the system of radiological protection, which in turn is strongly related to the core ethical value of dignity; that is, treating people with fairness and respect (Martinez and Wueste 2016, ICRP 2018). In other words, although we might generally think of inclusivity as being synonymous with stakeholder involvement and public engagement, it also includes equitable professional development, care and respect for our colleagues (Martinez 2020). A true diversity of backgrounds, cultures, experiences, abilities, etc, will necessarily result in a variety of perspectives that are important to consider for both ethically and technically sound outcomes in radiological protection. Elevating women's voices, mindfully including or promoting women in additional minority groups, making spaces welcoming and accessible for more people (e.g. non-gendered restrooms, breastfeeding rooms) will improve morale and a sense of belonging to the community; and we are a community, standing in solidarity with our members with intention and empathy to make sure that each voice is heard, respected and valued (Martinez 2018).

2.1.2. Improvement of the RP culture through a gender perspective.

There are several ideas crucial to making an effective contribution when working to obtain social licence (i.e. acceptance) and address negative perceptions of radiation exposure, which unfortunately grow day after day. A few of these are emphasised here in the context of a gender perspective, with particular consideration for the themes of the IRPA Congress: Radiation Protection Culture and Public Empathy.

First, the concept of culture. A society's culture involves ideas, beliefs, habits, behaviours, knowledge, experiences and attitudes, which are developed, shared and accepted by people in that society (White 1959); it includes both scientific and social dimensions. The main purpose of this presentation, then, was to raise awareness on the relevance of considering a gender perspective when seeking to understand the development of every culture and here the construction of an RP culture. Like most nuclear science-related disciplines, RP has historically been a male-dominated field and, therefore, policies and strategies have been discussed, designed and established primarily by a masculinised approach.

Despite general agreement on the importance of diversity, women, while representing over half of the world population, still remain underrepresented in leadership positions and in decision-making at all levels (UN Women 2020), as is the case in RP organisations. In this regard, the persistence of gender disparities is clearly reflected in the unequal access women have to high-quality employment (Morton *et al* 2014), to higher education, to the highest echelons of scientific research (UNESCO 2015), and, in general terms, to opportunities for advancement both in their professional and personal life. In order to develop and maintain a diverse and inclusive RP culture, it is essential to integrate a gender perspective that ensures not only an active engagement of women, but also the identification and processing of their differentiated needs and visions, so that they constitute real, key components of the decision-making processes.

In RP, there is concrete evidence that women face obstacles mainly at four levels: socio-cultural, institutional, female subjectivity, and lack of gender solidarity (Ruiz Tena 2019). Firstly, there is a socio-cultural construction on the role women should play in a society that keeps them away from decision-making positions and developing professional careers in STEM subjects. This aspect is related to female subjectivity, which is also socially constructed and part of both the collective imagery and that of women themselves who are raised to be mothers and carry out domestic tasks, according to the established stereotypes. Lack of self-esteem, fears or insecurities are also elements of the education they receive from

home and already from kindergarten. At the institutional level, most regulations, statutes, organisational charts, etc are created by and for men, so women naturally enter a hostile environment, where a lack of gender consciousness prevails. Last but not least, our society has historically promoted enmity among the diversity of women, so that they have not been able to develop strong tools for networking or teamwork among themselves.

Applying a gender perspective to RP is also crucial to cope with one of its most important challenges: public communication and empathy, which is key for an effective implementation of RP measures. In this regard, women generally have a more negative perception of nuclear energy than men, and especially associated with the effects of ionising radiation. Thus, in order to bridge the gap of understanding between experts and society as a whole, action plans need to include dedicated strategies, with a corresponding budget, for developing an innovative narrative, and communicating from a gender approach.

In conclusion, it is vital to engage all key players, including high-level authorities, and educate them on the importance of gender mainstreaming in this particular field, considering that the above-mentioned obstacles have a direct negative impact not only on reaching gender parity, but also on the enhancement of an RP culture, and on achieving the required public acceptance.

2.2. Overview of the status of women in radiation and nuclear sciences

Two perspectives were offered related to the status or position of women in radiation and nuclear sciences or related fields.

Florence Maher and Jacqueline Garnier-Laplace spoke on developments within the Nuclear Energy Agency (NEA) related to efforts to support gender balance in radiation and nuclear sciences, the position of women in relation to radiological protection and advanced technologies, including highlights of the current situation, actions taken by the Organisation for Economic Cooperation and Development (OECD) Nuclear Energy Agency, and initial approaches towards improving the gender balance in the nuclear energy sector. Florence Maher is a social scientist in the Division of Radiological Protection and Human Aspects of Nuclear Safety at the OECD NEA (NEA RP-HANS). She previously served as a diplomat with the US Department of State, working on nuclear non-proliferation among other issues. She was a Rotary Peace Fellow at the International Christian University in Tokyo, Japan, where she completed a Master's degree in public policy and social research.

Dr Garnier-Laplace joined the NEA in May 2019 and is Deputy Head of RP-HANS. She serves as the Scientific Secretary of the Committee on Radiological Protection and Public Health. Previously, she was the Deputy Director in charge of Research for Radiological Protection at the French Institute for radiological protection and nuclear safety. She is currently the secretary of Committee 4 of ICRP. She has (co)-authored more than 110 peer-reviewed papers mainly dealing with various radiological protection scientific issues.

Rui Qiu presented data on the gender composition of the IRPA Young Generation in Nuclear (YGN) group, with additional perspective from China on female participation. Dr Qiu is an Associate Professor at the Department of Engineering Physics of Tsinghua University in China. She previously worked as a radiation physicist at Pohang Accelerator Laboratory in Korea and at SLAC National Accelerator Laboratory (formerly the Stanford Linear Accelerator Center) in the USA. She serves as a member of ICRP task group 103, Vice-chair of the Youth Committee of the Chinese Society of Radiation Protection, and Managing Director and Vice Secretary-General of the Chinese Society of Particle Accelerator Radiation Protection.

2.2.1. Position of women in relation to radiological protection and advanced technologies.

Countries that are part of the OECD show a low proportion of women in the fields of STEM and a very important gap in nuclear technologies and RP. This is a global problem affecting many countries to different degrees. Under-participation by women in STEM starts in school. Research shows that adolescent boys and girls perform equally in STEM subjects. However, women account for just 37% of new entrants into tertiary-level science programmes in OECD countries. On average in the OECD, only 31% of STEM graduates are women (OECD 2018a). Fewer girls studying STEM results in fewer women in the STEM workforce. This is a loss in qualitative and quantitative terms. Unlocking the full, diverse talent of society fuels innovation and productivity.

At the same time, a major demographic shift in the global workforce is underway. Previous generations are leaving the nuclear and radiological protection labour market. The professional pipeline of young people preparing to replace them is smaller than in the past. Fewer students of either gender are studying STEM, and the demand for trained staff is increasing. This has a direct effect on the ability of countries to maintain a highly qualified STEM labour pool and could have serious implications for the future. At the same time,

research shows that diverse teams have higher productivity and performance. Therefore, achieving gender balance is key to maintaining a sustainable, vibrant and skilled workforce.

2.2.1.1. Qualitative and quantitative data collection through ad hoc surveys in OECD member countries is necessary.

NEA member countries increasingly recognise the importance of gender balance and are seeking to improve it. Many women have seen their education and career plans disrupted by the global pandemic. This underscores the urgency of the challenge. The OECD NEA is currently working with its 34 member countries to collectively identify information and activities needed to develop policies and proposals to improve gender balance. In 2019, the Agency convened an exploratory meeting, which led to the NEA Steering Committee chartering a task group to develop evidence-based policy recommendations. Useful, practical data are needed on women in the nuclear sector, especially qualitative data to understand the barriers and challenges faced by women. Member countries are being engaged to collect quantitative and qualitative data that will be analysed and form the foundation for a future policy instrument. This will provide a useful international framework to guide and coordinate international and national initiatives on improving gender balance in the nuclear energy sector.

Gender balance is being further supported by the Agency in other strategic areas of international cooperation. The *NEA's new Global Forum on Nuclear Education, Science and Technology*, an essential initiative launched in January 2021 with the goal of providing a platform for sustained co-operation among academic institutions, policymakers and key stakeholders in the nuclear energy sector and civil society, features gender balance as one of its four strategic work areas.

In addition to developing policy, the Agency also promotes direct communications and engagement on gender balance. The NEA has organised seven *mentoring workshops* hosted since 2017 by some of the NEA member countries (Japan, Russia and Spain) that have proven to be very valuable for students to be mentored and inspired by distinguished female scientists from their home country and abroad. Three events are under preparation for 2021 (with partners in Kenya, Russia and Japan). These workshops encourage female high-school students to consider STEM fields, specifically targeting the crucial decision-making period when many adolescents choose their future career path. Research shows that adolescent girls exhibit less interest in and confidence in their abilities in STEM than boys, even though their academic performance is equal. The workshops target this gap, retaining female students in the STEM pipeline by motivating them to continue on to university studies in STEM subjects.

Through these initiatives, the NEA is helping to ensure the depth and breadth of the future nuclear and radiological protection workforce. Tomorrow's challenges require recruiting and developing today's best and brightest, and international cooperation is vital to tackle the gender balance challenge. In sum, the NEA's multinational activities contribute to improving the gender balance in the nuclear energy sector and radiological protection. A robust, diverse workforce drives innovation and productivity. Developing women in STEM is essential to maintain capacity and expertise for the future.

2.2.2. Roles that women have played in RP from the IRPA YGN leadership committee and from China.

RP is a multi-disciplinary subject involving mathematics, physics, biology, chemistry, management and many other fields, in which women could make significant contributions.

The IRPA YGN leadership committee includes 20 members, of whom 4 (20%) are women. These are Rui Qiu; Anna Michaelidesova, a researcher at the Nuclear Physics Institute of the Czech Academy of Sciences; Marina Sáez Muñoz, a Chemical Engineer and Doctoral Researcher in the Laboratory of Environmental Radioactivity of the Universitat Politècnica de València in Spain; and Cinthia Papp, who works at the CNEA—Nuclear and Radiation Safety Management, in Argentina.

A survey has been performed on the current percentage of female members among the total YGN members in the IRPA YGN leadership committee member states. Table 1 shows the preliminary results based on data from eight countries including Austria, China, the Czech Republic, France, Japan, Korea, Spain and the UK. This survey reveals that women make up a considerable percentage, ranging from 15.4% in China to 52.9% in Spain. The average proportion is 33.9%, unchanged from the 2017 data.

For China, the Chinese Society of Radiation Protection includes 119 council members of whom 12 are female. These women are outstanding representatives of their institution or company, with many serving as leaders of their RP team. The Chinese Nuclear Society holds a Women's Forum every two years as part of their annual conference. For example, the forum titled 'Innovation and Dedication' and 'Profiles of Women in Nuclear Industry of the New Era' were held in 2017 and 2019, respectively.

In general, women have played, and continue to play, a substantial role in RP, and better promotion can be expected in the near future, if guidance in schools and public science popularisation are undertaken.

Table 1. Proportion of females among YGN in several countries.

	Female	Male	Female proportion
Czech Republic	10	10	50.0%
Austria	32	62	34.0%
France	5	5	50.0%
Japan	11	35	23.9%
Korea	23	67	25.6%
UK	97	163	37.3%
Spain	36	32	52.9%
China	12	66	15.4%

2.3. Challenges and specific needs

There were several ideas, suggestions and recommendations posed in the Special Session related to the support and advancement of women, although three presentations focused in on more concrete needs and challenges faced by women with advice on how we might address some of these issues.

Renate Czarwinski spoke on strategies for building confidence in young women to overcome dated stereotypes along with recommendations for increasing awareness of professional opportunities. Czarwinski is a retired Head of Division on 'Safety and Security of Radiation Sources; Radiation Incidents; Type Approvals' in the Federal Office for Radiation Protection in Berlin, Germany. Prior to that, she served as Head of Radiation Safety and Monitoring Section of the IAEA. She was President of IRPA from 2012 to 2016, only the second woman to hold this position and the first in about 30 years. At present, she is the President of the German–Swiss Association for Radiation Protection and the current Chair of the IRPA16 ICPC.

Gabriele Voigt gave a detailed presentation on the importance of having early and continued mentorship for both mentors and mentees. Dr Voigt has retired from the IAEA as Director of the Seibersdorf Laboratories in Nuclear Sciences and Applications and Safeguards. She currently co-owns the consulting company r.e.m. Radiation Environmental Management in Germany where she is involved with radioecological research, lecturing and training. Dr Voigt has been active in gender equality activities for her entire career, most recently as the President of WiN Global for the 2016–2020 term.

Ruxandra Sapoi highlighted the challenges women face with respect to maternity leave (or lack thereof) with strategies for developing and maintaining inclusive policies in the workplace. Dr Sapoi is a Technical Director at Rodos—Dositracker Romania, a group of companies involved in individual dosimetry monitoring, radon and environmental measurements and distribution of radiation detection and measurement instruments. She is also an RP expert approved by the Romanian regulatory body, an associate member of the European Dosimetry Group, a member of the Romanian Society for Radiation Protection and a founding member of Women in Nuclear Romania.

2.3.1. Main needs and challenges faced by women as shaped by safety and RP culture.

It is essential to assess gaps, difficulties and cultural issues faced by women, but also to embrace successes that help overcome resistance to change and old-fashioned behavioural patterns.

Women are an emerging economic strength in our modern world; what are their primary needs? First is the appropriate and unrestricted knowledge of the field as well as interest in this work. The woman who wants to work in an RP-related field—independent of her specific focus (i.e. technical, medical, regulatory or research), and this is true for any other professional career—needs adequate education and training for the job to know, evaluate and communicate both the features and risks connected to the work. She also needs social and ethical competence along with confidence in her knowledge, ability and overall esteem as a person. She must know what she wants and should have a vision of how to implement it, being mindful of financial resources, e.g. for project management, including those necessary for training for young professionals or for participation at important events like seminars or conferences.

Meeting these needs is a challenge for women working in RP-related fields, particularly related to assuming and balancing responsibilities without fear of failure. In addition, building networks with like-minded experts or participating in such networks, e.g. to meet and justify important goals in RP, can be a challenge.

Raising awareness of possible professional and employment opportunities especially among young students in order to increase their interest, participation and commitment is a widespread endeavour with responsibility shared across different shoulders, e.g. a university professor should be committed to RP and the recruitment, education and energising of students in this field; professional organisations have

responsibility for further training and providing networking opportunities, mentorship, etc. Methods/issues for raising awareness include:

- National and international networking, e.g. WiR, WiN
- Active membership in RP societies
- Active participation in dialogues on selected topics
- Job fairs
- Cooperation of professional societies with universities
- Internships, field trips.

These approaches should be carefully analysed. IRPA could develop a guidance paper for application by Associate Societies and provide a platform for networking by initiating appropriate dialogues.

2.3.2. Mentoring strategies.

Women in the nuclear industry and other nuclear application areas, such as RP, emergency preparedness, and environmental and agricultural nuclear applications, are underrepresented and on average contribute only around 20% of the workforce, or even less specifically in leadership positions (United Nations Office at Vienna 2018). There are several contributing factors to this lack of parity, including that many women, after completing their education and obtaining a degree, either take a break due to motherhood or family commitments or experience a glass ceiling in their career due to their gender.

Presently, there are a few initiatives to improve gender diversity, equity and balance in a variety of institutions, with the goal of achieving gender parity within the next couple of years (UN, IAEA and others). Efforts to this end include measures to employ more women in senior positions and retain women at all employment levels by offering good employment conditions and an acceptable work–life balance. Another important action is to attract young women to pursue a related professional career and offer scholarships and training opportunities to enter and progress in nuclear sciences.

Mentoring is an important means for effective networking, career development and professional promotion. The benefits and different approaches to mentoring were presented and discussed, including how WiN Global and international non-governmental organizations (NGOs) are contributing to the mentoring of women working or intending to work in the nuclear sciences. Mentoring, especially of women, should be implemented early on as an integral part of any institution for education and training in STEM fields of young students, mature professionals, and all those in between. Mentorship should begin even before university, to attract attention and open new opportunities. The mentor and mentee should be engaged to obtain maximum benefit for both parties: the mentee to access a network and have an understanding peer, and the mentor to share experience and guide the mentee during her career. Mentoring might result in a long-lasting relationship between mentee and mentor, and the most gratifying outcome is the success of a mentee in achieving her goals. In general, a mentor can act as a mentee and a mentee can mentor depending on her expertise and networks.

2.4. Maternity leave and gender equality—creating opportunities for women to stay connected with the workplace environment

Not only in the nuclear field but in general many women quit working after pregnancy, or they find difficulties in reconnecting with the working environment when returning to work. Around the world, the maternity leave period varies from none to 160 weeks (figure 1), and working women face two different challenges:

- Short maternity leave may lead to women quitting their jobs in order to take care of their children
- Long maternity leave may lead to women finding difficulties in reconnecting with the working environment.

Employers as well as institutions can support re-entry into professions by providing means to stay connected and scientifically up to date. This may include participation in meetings and conferences (online), personal meetings, easy access to libraries and media and institutional homepages, and involvement in projects.

International scientific organisations such as IRPA could help these women in overcoming the challenges that arise after returning to work by:

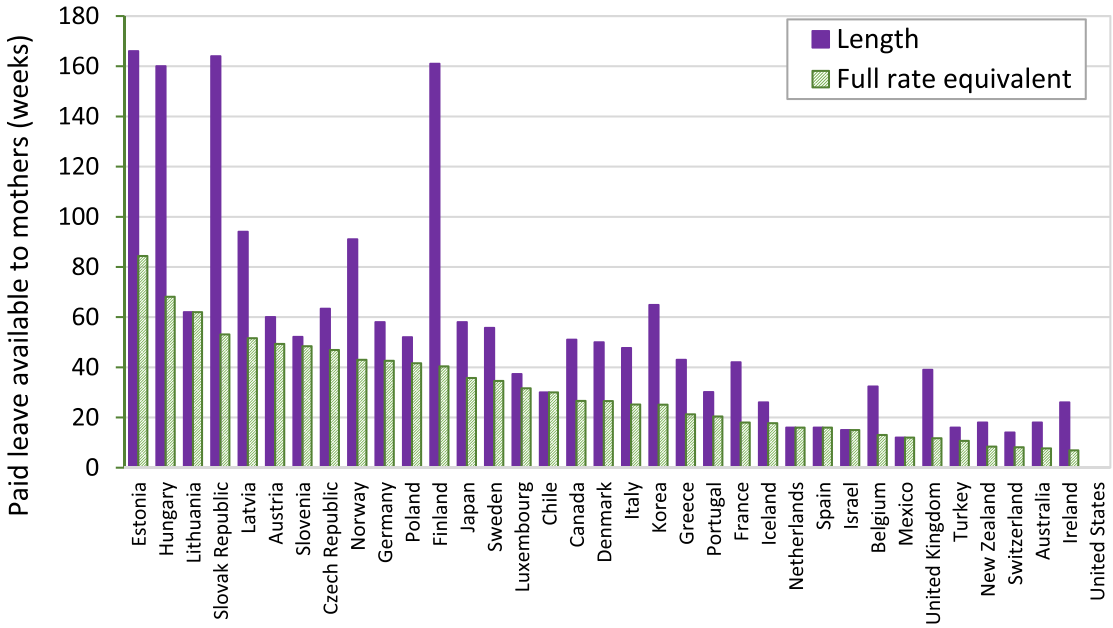

Figure 1. Paid leave available to mothers around the world, including maternity leave and parental/home care leave. Data from OECD (www.oecd.org/els/family/database.htm).

- Encouraging regional IRPA organisations to work with women on maternity leave and continue to involve them in IRPA activities to help them keep in touch with the working environment,
- Promoting IRPA's experience in long-distance collaboration and sharing it with the employers in the nuclear field, proposing an implementation of programmes such as keeping in touch during the maternity leave with work-from-home opportunities after the maternity leave ends, and
- Encouraging young women to contribute to IRPA's activities and to keep in touch during maternity leave.

2.5. Role models and women in leadership—examples

Although all the women on the panel currently serve and/or have served in various leadership positions, two presenters offered their perspective and advice from their time in their current roles, each serving as a chair of an international organisation.

Claire Cousins gave her perspective as the first (and only) female Chair of the ICRP Main Commission, advocating for the pro-active pursuit of gender parity. Dr Cousins is an interventional radiologist, most recently serving as the Lead Vascular and Interventional Radiologist at Addenbrooke's Hospital in Cambridge, UK, from which she retired in 2016. She has served as Chair of the ICRP since 2009 and will step down from that position in 2021.

Gillian Hirth discussed her path to leadership roles on the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), describing the importance of both mentors and peers in the encouragement of women working in the radiation sciences. Dr Hirth is the Deputy Chief Executive Officer and Chief Radiation Health Scientist of the Australian Radiation Protection and Nuclear Safety Agency. She is the current Chair of UNSCEAR and was recently elected to the Main Commission of the ICRP, having previously served on Committee 4. She is also on the International Union of Radioecology Board of Council. Their statements are given in the text blocks.

ICRP and Women in Radiation (Dr Claire Cousins)

The ICRP has been in existence for over 90 years. It was several decades before women were part of the organisation and since then they have had a very minor role in the leadership positions. In 1988, after 60 years, a woman finally joined the Main Commission. To date, six women have been Main Commission members and I am the first and only woman to be the ICRP Chair. After twelve years in the role, I am soon to step down and hope I have shown that women can have clear thought and vision to not only promote radiological protection but to also develop

strategies and initiatives to lead and improve the function of an organisation.

Any leader of an organisation needs the backing of a fully supportive team and I am grateful for those who have helped me realise my aims and ambitions. At times in the international arena, I have had to be a diplomat, mediator, ambassador and politician. Women can bring sensitivities and perspectives that differ from men in many areas of leadership.

During my time as Chair, I have increased the openness and transparency of ICRP and demonstrated that this is not just an 'old boys' club' that women have little hope of joining but a more modern institution with a formal election process. The number of female members has gradually risen with time to the current 25% and I am pleased to announce that for the next term this figure will be over 30%.

It is well known that even if women enter the workforce, over time they tend to steadily vaporise from the higher echelons of any organisation's hierarchy due to perceptions of their own capability and lack of confidence. ICRP members are all volunteers, and many women may be deterred from joining due to the extra commitment required, in addition to their daily jobs and family life. The issues of work life balance are extremely important and should not be underestimated, but many women, in all kinds of roles, manage complicated lives very successfully.

I am aiming to encourage young professionals, and particularly women, to join ICRP at a younger age and one way is now through our mentorship programme. Mentees are appointed to a Task Group, initially for one year on a part-time basis, with an ICRP member as a mentor and with a defined task. The system will allow mentees to learn how the organisation operates and, by being involved in the work of ICRP, hopefully they will subsequently consider nomination for Committee membership.

Women have much to offer ICRP and likewise ICRP can offer women a stimulating environment in which to meet scientific experts and those at the cutting edge of radiological protection. It is hoped that female membership of ICRP will continue to grow in the future as the system of radiological protection continues to evolve and be revised.

UNSCEAR (Dr Gillian Hirth)

UNSCEAR is a scientific committee of the United Nations, established by the General Assembly in 1955. The Committee is composed of scientific experts nominated on the basis of their scientific qualifications, experience and expertise by 27 countries that are Member States of the Committee. Being elected and appointed to be the Chair of UNSCEAR is a privilege and an honour. UNSCEAR is an outstanding group of scientific experts and leaders across a broad range of expertise in radiation sciences. Attending my first session in 2013 was a daunting experience with a number of the UNSCEAR representatives and delegation members, highly respected experts in their fields, having more years of experience at UNSCEAR than I had in life. It was difficult to see myself, a (comparatively) young female scientific advisor on the Australian delegation as being someone who could be a leader within the Committee amongst these international experts. After that first session in 2013 I could never have imagined I would become the Australian Representative and Committee Rapporteur in 2017 and then the Committee Chair in 2019, and if I had looked through the history books, the evidence would support my beliefs. In 2019 I became the second female Chair of the Committee in 64 years, the only previous female Chair had been appointed during the 1970s. I was the first female representative of Australia and the 6th Australian Chair since 1955.

So how did I become the Chair of UNSCEAR? The first step in this process was for me to be appointed as the Australian representative on the Committee. I had a mentor and I had sponsors—key people who made the decision to step back and, even though they were more experienced to do this role, they put me forward. They provided the opportunity, they encouraged and supported me and pushed me outside my comfort zone. They believed I could do the job of representing Australia on the Committee, and as the Australian representative in 2017 I was elected by the Committee to be the Committee's Rapporteur for the 64th and 65th sessions. I then went on to become the Chair for the 66th and 67th sessions, a responsibility that was extended for one additional session in June 2021 due to the ongoing COVID pandemic.

So why was this encouragement to become the leader important? It was important because I became visible; and if others can see it, they can also believe it is possible. In 2019 after my election as the Chair I was congratulated by many of my female peers, who said it was fantastic to see that a woman could

finally become Chair of the Committee. But it was not just women who noted this appointment — some men also said it was great because they had daughters who loved science, and it was good to be able to identify female role models undertaking leadership roles and demonstrating that it was possible for women to achieve and be appointed to these positions. Remarkably, at the same time I had become Chair, the Committee also appointed three female vice-chairs, and this was largely possible because of the increasing number of female representatives who had been nominated by their countries, and could therefore be considered for these positions. When you look at UNSCEAR now, 11 of 27 (41%) Representatives on the Committee were female at our 67th session in November 2020. The first female Secretary of the Committee (a UN position) was appointed in April 2019, and the Committee's Bureau and advisors is 62% female/38% male. This provides for a range of views and voices in the discussion, and it is well documented that women bring different perspectives to men in many areas of leadership and communication.

So, encourage your female peers, your staff, your daughters. They may not see visible role models. They may not see in themselves what you may see. They may underestimate their own capabilities and experiences and lack the confidence. Become that mentor or sponsor and provide opportunities and, most importantly, believe in them and support them to do their best. While the United Nations has recognised Gender Equality as one of their key Sustainable Development Goals where change needs to be made, it is up to each country of the United Nations to consider, prioritise and support gender equality, and one way that this can be achieved is to encourage and appoint female representatives and alternates, who can then be selected by their peers to undertake roles such as that of Chair of a Committee like UNSCEAR.

I am proud of what I have contributed to the Committee over recent years in my leadership roles. I am also proud of what the Committee and its experts have achieved—five reports approved over the last two sessions. I have been a leader, and sometimes a diplomat and mediator, and as the Chair, also one of the main representatives for the Committee—but nothing I have achieved has been done alone. I have worked with a diverse range of scientists and experts, wonderful and very capable people who I respect, and as the Chair I am just one person in a team. But if I had not had the support, encouragement and the belief of others since I first became involved with the Committee, I would never have considered that becoming Chair of UNSCEAR was possible.

3. Panel discussion

In the panel discussion of the WiR session, a variety of women covering different age groups and representing different countries with diverse professional and cultural backgrounds touched on various gender aspects relevant to RP culture. Two additional women from those introduced previously participated in the panel:

Kazuyo Suzuki is a Program-Specific Assistant Professor in the Pre-emptive Medicine and Lifestyle-Related Disease Research Centre at Kyoto University Hospital in Japan. She and other women researchers from diverse areas organised a forum[12] held immediately prior to the 2018 'International Workshop on the Biological Effects of Radiation'. This forum was entitled 'Diversity Pioneering the Future: Beyond Social and Academic Borders' and focused on 'What Have We Learned from Fukushima? Dialogues between Citizens and Scientists Sharing Experiences, Sharing Knowledge, Creating the Future'.

Marina Di Giorgio, the session organiser and member of the IRPA 15 ICPC, is Second Vice-President of the Nuclear Regulatory Authority of Argentina, President of the Argentine Radiation Protection Society, a member of the Argentine delegation of UNSCEAR and lead writer of the Radiobiology chapter for the UNSCEAR expert group on 'Second Primary Cancer after Radiotherapy', and a member of WiN Global and WiN Argentina.

The international panel shared their personal experiences in career planning and leadership roles in their respective institutions along with different aspects of how gender balance and equality/equity can be achieved. These fell into six broad categories: (1) education, training, and networking; (2) recruitment, attraction, and promotion; (3) employment and retention; (4) work–life balance; (5) role models and mentoring; and (6) example strategies and good practices from other organisations (e.g., EIGE 2016, WINS 2021) with respect to inclusive work culture and top-management engagement/commitment.

In summary, a policy framework is called for to support countries in their efforts to strengthen women's contributions to the nuclear energy sector and radiological protection. Data are needed on the participation of women in the nuclear and radiological protection workforce and in graduate programmes in order to

[12] Please see www.rcnp.osaka-u.acjp/~ber2018/presympo.html#presympo.

better understand the potential causes and consequences of the 'leaky pipeline[13]', and in turn to assess the effectiveness of existing efforts and to design appropriate initiatives for the future. Increased and targeted engagement, including communications and greater support for educational activities and mentoring, can enable and enhance women's contributions in these fields. International cooperation is essential to achieve these goals.

4. Way forward—call for action

There are clear challenges to securing gender balance within the RP profession, but it is clearly to the benefit of the profession to ensure the full and active participation of women. Increasing women's involvement and retention in radiological protection presents similar challenges to those of women in other STEM fields, with additional features. Radiological protection is a complex and multifaceted, multidisciplinary field, requiring commensurate education and, ultimately, expertise. Career paths in radiological protection are similarly varied with multiple opportunities in research, policy and regulation with many positions requiring practical radiological protection knowledge and skills. This variety of skills and jobs could play a significant and positive role in attracting young people, including young women, into radiological protection. Furthermore, it is widely recognised that there is a growing need for radiological protection expertise in various sectors (including the nuclear industry, non-nuclear industries, research and medicine). Unfortunately, the breadth of opportunities in the protection professions is not well known or understood outside of those currently in the field and can often be negatively impacted by public images and perceptions, in particular by the general fear of radiation that has arisen from nuclear accidents and from the global nuclear history of the past 70 years. Collectively, we need to work to correct this potentially biased image of what the modern radiological protection profession is and could be.

The 'pipeline leak' can represent a significant loss of talent or interest and/or lack of equity in career progression. For example, there is a striking figure that emerged from an enterprise survey conducted by International Labor Organization (ILO) in 2018 (ILO 2019). For enterprises that reported a gender balance (i.e. 40%–60% women) in their workforce, the proportion of women declines with the management level, such that only 5% of top executive and CEO positions are held by women. Collective action is needed, starting with the use of diverse mentoring and coaching programmes in our workplaces.

As a result of the IRPA 15 Special WiR Session, a recommendation was made to IRPA **to create an IRPA Task Group**. This task group would serve to promote a wide exchange of experiences and values from a gender perspective in RP within IRPA. The conclusions of the task group will permit an evaluation of the real opportunities, roles and policies that are exercised in the workplace in different countries to promote and trigger actions with a view to improving equal opportunities.

It is recommended that IRPA should play a key role in this by developing a Manifesto for Gender Equity. Some key components of such an approach would include

- Encouraging all organisations to develop Senior Management Commitment. This might be expressed by a written posted statement, by an approved Gender Policy and/or by the introduction/nomination of a gender focal point(s)[14]. It has been proven that this position needs to be at a high senior level to be able to implement gender-inclusive policy, best as a stand-alone office or within the office of the institute's highest level to be most efficient and accepted by all stakeholders.
- Providing a gender-friendly environment. With the commitment of senior management, the institutional culture will be driven towards inclusive, pro-diversity behaviour on all levels. This can be further enhanced by introducing awareness training courses on diversity and intercultural behaviour and attitudes, particularly in international organisations. The implementation of an unbiased work–life balance strategy and compensation/award systems will benefit any organisation with committed employees. There is an important role for IRPA Associate Societies around the world, which should be encouraged to provide dedicated support for the full participation of women; for example, including during and returning from maternity leave.
- Establishing policies against (sexual) harassment with clear, consistent and stringent consequences on non-compliance.

[13] The 'leaky pipeline' is a metaphor often used to describe how the number or proportion of women decreases across the education and career pipeline.

[14] A key position dedicated to advocacy. See, for example: www.unwomen.org/en/how-we-work/gender-parity-in-the-united-nations/focal-points-for-women.

- Focussing on mentoring and active engagement of role models. The introduction of mentoring programmes, including training programmes both in gender issues and in leadership, will help to enable climbing the career ladder, improving access to existing networks, and the overall benefitting from mentors' experience and expertise.
- Enhancing gender solidarity, friendly recruitment strategies and networking, and bridging the generation gap. This would include active cooperation with gender/diversity networks and NGOs, universities and other science organisations, in particular Young Generations Associations. Partnerships with such will allow specifically for recruitment and employment after service or separation, and to provide a national and international network of access to employment and development opportunities.
- Emphasising the multi-disciplinary nature of the RP field and professional, so that it attracts a wide range of candidates, facilitating the sharing of good practice across the profession. Contractual situations specifically for women and the option for future career developments should be provided. This calls for unbiased and objective performance evaluations and patronage of individuals with potential.

The proposed actions are of a generic nature and can be applied to any science, not only RP, where there is an imbalance of diversity. They are derived from a variety of recent questionnaires (e.g. most recently NEA) and initiatives (e.g. World Institute for Nuclear Security (WINS) and IAEA Department of Nuclear Energy) on how to improve gender balance in nuclear sciences and related fields.

Finally, gender balance and equality/equity must be at the heart of any strategic plan for the future of the radiological protection profession. To succeed, we must first take action for fairness and gender parity at all levels. We believe that international cooperation between relevant bodies is essential for success and could serve as a catalyst for specific policy statements aimed at achieving balanced representation of women in radiological protection.

Acknowledgments

The authors have confirmed that any identifiable participants in this study have given their consent for publication.

ORCID iDs

Gabriele Voigt https://orcid.org/0000-0003-1817-2831
Nicole E Martinez https://orcid.org/0000-0002-7184-3043
Jacqueline Garnier-Laplace https://orcid.org/0000-0002-3486-147X
Florence Maher https://orcid.org/0000-0001-6835-2991
Claire Cousins https://orcid.org/0000-0001-6478-8552
Gillian Hirth https://orcid.org/0000-0002-5478-1127
Renate Czarwinski https://orcid.org/0000-0002-3416-8229
Ruxandra Sapoi https://orcid.org/0000-0002-0462-8239
Kazuyo Suzuki https://orcid.org/0000-0001-5716-5242
Rui Qiu https://orcid.org/0000-0002-3511-6164
Melina Belinco https://orcid.org/0000-0001-7206-0676
Marina Di Giorgio https://orcid.org/0000-0001-8946-5530

References

EIGE 2016 Gender equality in academia and research—GEAR tool (https://doi.org/10.2839/272753)
Ferdman B M 2017 Paradoxes of inclusion: understanding and managing the tensions of diversity and multiculturalism *J. Appl. Behav. Sci.* **53** 235–63
Ferdman B M 2013 Frameworks for understanding inclusion *Diversity at Work: The Practice of Inclusion* ed B M Ferdman and B R Deane (San Francisco, CA: Jossey-Bass)
Gillenwalters E and Martinez N 2017 Review of gender and racial diversity in radiation protection *Health Phys.* **112** 384–91
ICRP 2018 The ethical foundations of the system of radiological protection. ICRP Publication 138 *Ann. ICRP* **47** 1–65
ILO 2019 Women in business and management: a global survey of enterprises, 149 pages, ILO publication, bureau for employers' actvities (ACT/EMP), survey: women in business and management: a global survey of enterprises (ilo.org)
Martinez N E 2017 Contributions from women to the radiation sciences: a brief history *Health Phys.* **112** 376–83
Martinez N E 2018 Women in the radiation sciences and the importance of building community *Health Phys.* **115** 547–9
Martinez N E 2020 The 2018 bo lindell laureate lecture: finding common ground between science, ethics, and experience *Ann. ICRP* **49** 9–31
Martinez N E 2021 Women in radiation: a brief discussion of the intersectionality of race and gender *J. Radiol. Prot.* **41** 590–6
Martinez N and Wueste D 2016 Balancing theory and practicality: engaging non-ethicists in ethical decision making related to radiological protection *J. Radiol. Prot.* **36** 832–41

Morton M, Klugman J, Hanmer L and Singer D 2014 *Gender at Work: A Companion to the World Development Report on Jobs* (English) (Washington, DC: World Bank Group)
Muhs G G, Niemann Y F, González C G and Harris A P 2012 *Presumed Incompetent: The Intersections of Race and Class for Women in Academia* 1st edn (Logan: Utah State University)
O'Donovan D 2018 Diversity and inclusion in the workplace *Organizational Behaviour and Human Resource Management. Management and Industrial Engineering* ed C Machado and J Davim (Berlin: Springer)
OECD 2018a *Education at a Glance 2018: OECD Indicators* (Paris: OECD Publishing) (https://doi.org/10.1787/eag-2018-en)
OECD 2018b OECD Family Database (available at: www.oecd.org/els/family/database.htm)
Ruiz Tena C 2019 *Las mujeres en su intersección. Cuadernillo 1. Serie 'SISA—Mujeres Activando'* (Buenos Aires: Asuntos del Sur, con el apoyo del International Development Research Center (IDRC))
Suzuki K *et al* 2015 Qualitative interview of women in research and development to clarify universal factors which induce 'inclusive innovation' *Astronomy in Focus, Volume 1, XXIXth IAU General Assembly, August 2015* ed P Benvenuti
UN Women 2020 COVID-19 and women's leadership *From an Effective Response to Building Back Better, UN Women Policy Briefs* (https://doi.org/10.18356/639a046a-en)
UNESCO 2015 *Science Report: Towards 2030* (Paris: UNESCO Publishing)
United Nations Office at Vienna 2018 Strategy for gender equality and the empowerment of women (2018–2021) (United Nations)
White L 1959 The concept of culture *Am. Anthropol.* **61** 227–51
WINS 2021 International best practice guide on advancing gender parity in nuclear security, Vienna