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Alarm sounded over declining US radiation professional workforce

As retirements surge, shortages threaten to slow advances in cancer therapy, diagnostics, and improved understanding of the physiological impacts of radiation.

"We've never had a baby boom before, and we've never seen the loss of such a large proportion of the workforce in such a short time," says Wayne Newhauser, a medical-physics professor at Louisiana State University. Newhauser led the review that makes up the December 2022 special issue of the *Journal of Applied Clinical Medical Physics* (*JACMP*); the review provides a snapshot of the status of the major radiation professional workforces in the US.

Workforce shortages are compounded by newly trained scientists who choose to leave their fields for other opportunities. Charles Ferguson, director of the Nuclear and Radiation Studies Board at the National Academies of Sciences, Engineering, and Medicine, has heard reports of radiation professionals trained at the Department of Energy's Hanford nuclear site in Washington State being snapped up by Amazon and Microsoft for jobs that are unrelated to their field. "People in these professions are smart and trainable, and they can quickly tool up to work in the technology industry," he notes.

A lack of interest from incoming students has led to the closure of many academic programs in most of the radiation specialties, say Newhauser and others, and has resulted in a lack of capacity to train new professionals.

Werner Rühm, who directed Helmholtz Munich's Institute for Radiation Protection until its closure last year, says Germany has also experienced declining interest in radiation sciences. Germany's renunciation of nuclear power has led many people there to conclude that radiation protection is no longer necessary. The country's Ministry for the Environment, Nature Conservation, Nuclear Safety, and Consumer Protection is working to shore up competence in the sciences, in part by communicating its continued importance, Rühm says. "Radiotherapy is the most successful cancer therapy to date. To develop it further, you need competence in radiation science."

The exact size of the professional radiation workforce is hard to determine, in part because of its fragmentation among different fields and its sometimes ambiguous definitions and qualifications. The *JACMP* review, which took the authors seven years to complete on a pro bono basis, includes estimates that vary in fidelity depending on the field; some of the radiation specialties do not keep figures at all.

Health physics

Health physicists aim not only to protect workers, the general population, and the environment from the ill effects of radiation but also to ensure radiation's beneficial uses, which include laboratory research, mining, oil and gas exploration, nondestructive testing, and brewing. The *JACMP* review estimates the health-physics workforce at anywhere from 3200 to 7000 persons, depending on the definition used. The Health Physics Society reported a membership of 3081 in 2020, down from its 4277 members in 2013. Those figures likely understate the actual number of health physicists in the US, the review says.

About half of health physicists in the US work in nuclear power plants, according to the *JACMP* review. The rest are spread across industries where workers use or are exposed to ionizing radiation.

Qualifications for health physicists vary widely. Eligibility for full membership in the Health Physics Society, for example, requires anywhere from a PhD to five years of experience without a formal health-physics degree.

The Nuclear Energy Institute, the trade group for the US nuclear technologies industry, told Newhauser and his coauthors that just 400 of the 3700–3800 radiation protection staff in nuclear power plants are required to have a four-year degree in health physics or a related field.

Emily Caffrey, program director of the health-physics program at the University of Alabama at Birmingham, says a steady decline in the number of health physicists has occurred over recent decades and has spanned every industry where they are employed. "Shortage is an understatement," she says.

Caffrey and others blame the partial meltdown at the Three Mile Island nuclear plant in 1979 for the plunge of interest in all the radiation-related professions. The accident resulted in a dramatic slowdown in construction of new nuclear plants. Many students at the time felt that

MEDICAL PHYSICIST Becky Guidry (left), of the Mary Bird Perkins Cancer Center in Baton Rouge, Louisiana, shows trainee Bijoyananda Adhikary how to work with a quality assurance device being used on a diagnostic CT scanner. The images taken by this CT scanner will help in planning computer-optimized radiation therapy that employs x rays or electrons.


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"nuclear stuff is just going to go away," she says. The 1986 Chernobyl disaster only reinforced that attitude.

But the market for health physicists is strong. Thomas Johnson, a professor of health physics at Colorado State University, runs a job board that lists about 80 openings each month. About three-quarters of the advertised positions require a bachelor's or graduate degree, most often a master's. Many of the postings remain unfilled for months, he says.

Around 18 academic institutions in the US offer accredited bachelor's health-physics programs, the review says. That's roughly half the programs that once existed. Twenty-three institutions currently grant master's degrees and 17 award PhDs.

"All the programs are in trouble with recruiting," Johnson says. "They're all very concerned about being closed for lack of students or lack of funding." Colorado State currently has 15 master's and PhD health-physics students, and the department will be starting an undergraduate program soon in hopes of attracting more students to the graduate level. But the program had to turn away two or three students this year because of inadequate funding.

"The bulk of our students are attracted to or working for the Department of Energy, yet DOE has no funding for training health physicists," Johnson says. DOE's national laboratories employ around 400 full-time health physicists in positions that generally require a bachelor's degree or higher in a related discipline, according to the *JACMP* review. Some funding for health-physics education in the US is provided by the Nuclear Regulatory Commission.

"The biggest problem is getting the word out that this is a job that's interesting, in high demand, and pays well," Caffrey says. "If you were to survey health physicists, a very high percentage would say they found [their careers] by accident or were told about it when they were halfway through a physics degree. People just don't know about it."

Starting salaries for health physicists vary widely, says Johnson. A master's degree holder could make more than $100 000 at a federal facility, while a state agency might offer less than $50 000. "It's highly unusual for a highly qualified student to go to work for a state. So some states have been hiring people with a degree in biology or another science and sending them to training classes to qualify them," he says.

Radiation biology

Already the smallest of the radiation professions, radiation biology is the most endangered, at least in the US, the *JACMP* review says. Jacqueline Williams, a radiation biologist at the University of Rochester and an author of the review, describes the field as seeking to determine the exact impacts of radiation on tissues: "how molecules in the cell react, how the cell reacts, how the tissue reacts, and how the organism reacts." It differs from medical physics, which deals with the application of physics to the diagnosis and treatment of human disease.

Radiation biology has been in decline for about the past 40 years, says Williams, when radiation oncology departments were unable to find enough radiation biologists to train their residents. As a result, the accrediting board dropped its requirement for a radiation biologist to be on staff of those departments. "By just saying we don't need a radiation biologist, they made it worse," she says. "What had been a declining profession suddenly became a dying profession." The change also led to a "watering down" of the radiation-biology component of residents' training, Williams laments.

Further contributing to radiation biology's decline was the termination in 2016 of DOE's long-running research program on the health effects of low doses of ionizing radiation. Congress has ordered DOE to reinstate the program, and House and Senate appropriators have included $20 million in their pending fiscal year 2024 spending bills for that purpose. A 2022 report by the National Academies recommends funding of $100 million per year for that research program.

Retirements continue depleting the ranks of the 500 or so remaining US radiation biologists. The last two formal radiation-biology training programs in the US were closed a decade ago, and Williams says anyone interested in entering the field would need to get into the lab of a qualified biologist who is working hand in hand with a medical physicist.

The decline of radiation biology won't put patients at risk, but it could impede further progress in radiation oncology, Williams says. "Oncologists have become mere applicators; they use their fancy machines [without] necessarily understanding the biology behind them."

Radiation biology is in less dire straits in Europe, says Andrzej Wojcik, a radiation biologist at Stockholm University, home to Sweden's sole radiation-biology program. He's funded by the Swedish Radiation Safety Authority and by Euratom, the international nuclear organization of European Union members. The EU also has a low-dose-radiation research initiative, which helps to keep the discipline alive there.

France and Germany have dedicated research support for radiation biology, as does the nonprofit Cancer Research UK. But Belgium's general radiation-biology program is being refocused on nuclear waste, the environment, and radionuclide terrorism, says Wojcik.

Williams and Wojcik both say that

Aspect	Health physics	Medical physics	Medicine	Nuclear engineering	Radiation biology	Radiation and nuclear chemistry
Size (number of workers)	3200–7000	8000	37 600 (34 000 radiologists, 3600 radiation oncologists)	18 000	~500	Estimate not available
Trends in workforce size	Shrinking	Growing; shortages in some subspecialties	Changing practices in radiology and radiation oncology affecting workforces	Slight growth; aging workforce lacking in diversity	Shrinking; shortages due to aging workforce, failure to replace	Shrinking; shortages due to aging workforce
Factors driving future trends	Closure of power plants	Increasing demand due to population growth/aging	Aging/retirements, employment choices (full vs. part time), use of AI	Increase in nonpower applications (for example, nuclear security)	Aging/retirements, reduced funding	Aging/retirements, reduced funding
State of education and training	Small capacity; risk of program closure	Limited residency positions may affect the future pipeline	Adequate capacity	Adequate capacity	Complete loss of training programs	Risk of future inability to maintain the workforce
Future outlook	**Poor**	**Good**	**Good**	**Good**	**Poor**	**Poor**

A SUMMARY of the workforce health of the radiation professions shows several with worker shortages and declines in the number of education and training programs. (Adapted from W. D. Newhauser et al., *J. Appl. Clin. Med. Phys*. **23**, e13846, 2022.)

radiation biologists would be essential in the response to a radiological catastrophe, such as a nuclear bomb or dirty bomb detonation. "There is almost no medical [response] if there is some kind of large-scale disaster," says Williams. "The physicists can wander around with their meters; the radiation oncologists will hide. It's the marriage of the biologists and the physicists that will actually guide public health in those circumstances."

Medical physics and radiology

The International Organization for Medical Physics counts nearly 30 000 medical physicists worldwide. The roughly 8000 members of the American Association of Physicists in Medicine have earned a master's or doctoral degree in physics, medical physics, biophysics, radiological physics, medical health physics, or equivalent disciplines. Members must also be certified in their specific subfields, which include therapeutic, diagnostic, and nuclear medical physics.

Medical physicists maintain and calibrate the equipment used in diagnostic and therapeutic radiation. They also help to improve the targeting and delivering of radiation to patients and advise radiologists to ensure that a patient won't receive an excessive radiation dose when multiple x rays or CT scans are ordered. "The physicist needs to be sure to get the amount of radiation to where the oncologist wants it, taking into account a specific patient's anatomy and the healthy structures around the tumor," says Lydia Wilson, a medical physicist and assistant professor in the radiation oncology department at Sidney Kimmel Medical College and Cancer Center in Philadelphia.

The medical-physics workforce is currently adequate in size, says the *JACMP* review, but there are indications of shortages developing in some subspecialties, including diagnostic imaging and nuclear medicine. The review notes that although the education pipeline is sufficient for current needs, bottlenecks could result from a shortage of residency training positions.

Newhauser worries that the medical-physics profession won't be able to respond quickly enough if the need arises. "It may take 5 years to train a PhD, but a fully qualified medical physicist may take 10 to 12 years," he says.

Several factors, including burnout, a trend to part-time work, and skyrocketing demand for medical imaging, have led to a nationwide shortage of radiologists, says Edward Bluth, chair emeritus of the radiology department at Ochsner Health, a multispecialty clinic in New Orleans. The US "produces about 1200 diagnostic radiologists each year, but larger numbers are leaving," he says.

Artificial intelligence could alleviate some of that shortage. "If AI makes radiologists more efficient and reduces some of the work we do, then the volume of radiologists may be adequate," says Bluth.

Nuclear engineers

Nuclear engineers are mainly employed in the design and support of nuclear reactors and the nuclear fuel cycle. In the near term, a reduction in personnel because of recent and upcoming nuclear power-plant retirements is being partially offset by a need for personnel to decommission the plants, the *JACMP* review says. The hiring of young engineers into the existing workforce appears to be sufficient to meet current demand, it states. A gap in mid-level management may soon appear, however, because of the large number of senior personnel who are expected to retire over the next decade.

Shaheen Dewji, an assistant professor of nuclear and radiological engineering and medical physics at Georgia Tech, says the US demand for engineers is growing in the national security sector. She points to the National Nuclear Security Administration's formation of four large university consortia to create

a pipeline that would match trained nuclear engineers and other nuclear professionals with national security needs. Each has a different thrust, including fundamental research, enabling technologies, and arms control monitoring and verification.

Radiochemistry

Radiochemistry traces its roots to the wartime Manhattan Project, when chemists devised methods of separating plutonium from the other components of spent nuclear fuel, says Brian Powell, the Fjeld Professor in Nuclear Environmental Engineering and Science at Clemson University. More than a decade ago, the National Research Council warned of a wave of impending retirements coupled with a dramatic decrease in the numbers of students opting for careers in nuclear chemistry and radiochemistry. The National Academies' Ferguson says it may be time to revisit the workforce issue, although he hasn't yet proposed a study.

Newhauser and his coauthors were unable to estimate how many scientists are working in radiochemistry and nuclear chemistry. The number of training programs has fallen over the past few decades, and today only Florida International University and the University of Nevada, Las Vegas, offer a radiochemistry PhD in the US. Other radiochemists receive their formal degrees in chemistry, so it is difficult to track their numbers.

Today, radiochemists are in demand to work on the environmental cleanup of nuclear waste, in national security, and on research on materials needed for advanced reactors, to name a few areas. The PhD and master's students who are graduating from Powell's program are being hired immediately, mostly by DOE national laboratories.

Addressing the shortages

Newhauser says workforce concerns must be addressed "systematically." He recommends the creation of an advisory board at the national level to make recommendations for the short, medium, and long terms. "What hasn't worked is to leave it to the professionals, . . . DOE and the politicians," he says. Federal funding agencies need to coordinate their efforts. Data on the workforces, education pipelines, and projected needs should be collected and assessed annually to see where attention should be devoted.

At a symposium held in November 2022, the standards-setting International Commission on Radiological Protection (ICRP) called for actions to strengthen expertise in the radiological protection workforce worldwide, including increased government funding for research at universities and national laboratories. The ICRP also urged universities to develop undergraduate and graduate programs and to increase student awareness of job opportunities in radiation-related fields.

Rühm, who now chairs the ICRP, notes that 50 of the group's 360 members are mentees. The students bring new ideas to the ICRP committees and task groups, he says, and their participation helps make the occupations more attractive to young people. Other radiation professional organizations, he suggests, might follow suit.

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