PREVIOUS INFORMATION

NUCLEAR AND RADIOCHEMISTRY

Of all isotope sectors, this pair of subdisciplines has suffered by far the greatest losses and has been the subject of the most alarms. They are so critical to training, research and practice in nuclear medicine, science and technology that, in the isotope community, its problems have drawn the greatest attention.

A 1973 survey (19) of American Chemical Society-approved academic chemistry departments found that the percentage of them offering nuclear courses had dropped from 53% in 1964 to 45%. (Since the total number of chemistry departments had grown during those nine years, the lower figure may have resulted from new departments omitting nuclear chemistry, rather than from changes in the existing ones.)

Then the situation worsened, for two reasons: falling research funding and the 1973 transfer of research funding of nuclear chemistry from the Atomic Energy Commission's chemistry office to its physics office. Alarms and entreaties were not heeded. (21) Thereafter, almost no hiring of new faculty in nuclear chemistry was done.

Between the academic years 1977 and 1981 the number of doctoral candidates in the most central parts of nuclear and radiochemistry fell by half. At that time, when needs for doctoral nuclear and radiochemists were significantly increasing, doctorates awarded fell from 68 to about 30. (20)

In 1988 a group of accomplished people concerned with uses of isotopes gathered in a National Research Council Workshop to consider the problems they faced because their requirements for experts well trained in nuclear or radiochemistry were threatened or not being met. (3) They represented fields including nuclear medicine, nuclear weapon materials, radiopharmaceuticals, environ-mental science and technology, the nuclear power fuel cycle/waste management, isotope production and new developments.

Among their observations: "The future vigor and prosperity of American medicine, science, technology and national defense thus clearly depend on continued use and development of nuclear tech-niques and use of radioactive nuclides. Loss of know-how in this field or failure to develop new uses for the technology could seriously and adversely affect this country's economic competitive-ness in many technological and industrial areas the supply of such people has been increasingly inadequate to meet national needs in the several sectors of medicine, science and technology."

The annual shortfall of people well prepared in nuclear and radio-chemistry was found to be in the hundreds. These numbers, although small, importantly impact a spectrum of fields of medicine, technology and security.

In the course of his/her career, one professor in radiochemistry prepares perhaps a few tens of teachers, each of whom then prepares large numbers of students for a spread of fields, from medicine to pharmacy to nuclear power to nonproliferation of weapons. Then a follow-on multiplier is seen, for example, in the laboratories of a typical radiopharmaceutical company, where the work of a handful of radiochemists enables the work of literally hundreds of other researchers. (36)

Participants in that 1988 workshop faced disturbing facts including decisions of university chemistry departments not to replace retirees in nuclear and radiochemistry, due to absence of an identified, significant funding source. One paradoxical result: between 1978 and 1988, while graduate student interest in nuclear and radiochemistry rose by 32%, faculty numbers fell by 60%. Equally startling was the finding that one-third of graduate students in nuclear and radiochemistry were at institutions offering no courses in nuclear or radiochemistry!

The contrasts between student interest and numbers of faculty and courses somehow defy the 1993 observation (4) that it was the accidents at Three Mile Island and Chernobyl which caused the observed drop in enrollments in these fields. (24) There can be no doubt, however, that sensational and exaggerated media reports of the accident at Three Mile Island, followed by the tragic disaster at Chernobyl, discouraged many young people's interest in nuclear careers.

The 1988 workshop participants saw "a great dependence on foreign trained scientists to fill existing needs." It was later noted, however, that this source cannot be counted on. (29)

Many other reports have pointed to the threatened loss of this centrally essential resource. (16, 22, 23, 25-28, 34)

The field of radiopharmaceuticals for nuclear medicine has felt an especially severe shortage of chemists. In 1988 "an incredible mismatch" was noted "between the contributions and roles of chemists in radiopharmaceutical development and current output of graduates in radiochemistry." (34)

Since most academic chemistry departments no longer include nuclear and radiochemistry courses in their curricula, many nuclear power plants felt the shortages and resorted to costly and narrower in-house training of their newly hired chemists. (27) National Laboratories attempted a similar stop-gap remedy: in-house courses and on-the-job training by senior staff members. This approach falls short, however, of imparting in a reasonable time "the broader skills, capabilities, and flexibility" that emerge from formal academic training. (23)

By 1991, degrees awarded, numbers of faculty and viable academic programs in nuclear and radiochemistry had fallen further. "Radio-chemistry and nuclear chemistry graduate programs are not in good shape." Faculty numbers nationwide (not including nuclear medicine and radiopharmaceutical chemistry) dropped from 180 in 1978 to 65 in 1992. Fewer than 8 radiochemistry doctorates a year were awarded. (24) Needs identified were: more laboratory facilities, faculty, students, student support and faculty research support by a clearly defined responsible unit in DOE or NSF.

A further alarm was sounded on finding a 25% drop in numbers of graduate students in master's and doctoral programs in nuclear and radiochemistry, from 127 in 1987 to 95 in 1992. (25)

In 1992, although there were 28 chemistry departments offering graduate courses in nuclear and radiochemistry, it was reported that most of them were down to one pertinent faculty member and incapable of awarding doctorates in this field. (26)

Due to the funding problems discussed above and to suspicion of anything nuclear, many bright students have shied away from nuclear science, despite increasing uses of radioactivity and nuclear techniques. (4) It is clear that the public, including students, would benefit from factual knowledge of the benefits, hazards and safe handling of radioactivity.

This segment of the isotope world, much depended on by other segments, is the one in the most trouble. If it is allowed to disappear, most of the other segments will be in worse trouble than now.

NUCLEAR MEDICINE, RADIOPHARMACEUTICALS AND RADIOPHARMACY

Nuclear medicine has had a profound impact, raising the quality and lowering the costs of health care. (38, 39) Today's practice of medicine depends on its faster and clearer diagnoses and alterna-tive treatments. It has benefited patients and physicians dealing with many kinds of cancer, heart disease, disorders of the brain, blood, bones, and other organs. Especially useful are positron emission tomography (PET), which quickly produces images of normal and abnormal biological processes, in the brain and many other organs, and the tissue-imaging technique, single-photon emission computed tomography (SPECT).

NIH and DOE

Nuclear medicine was born and nurtured in the research of DOE's predecessor agency, AEC. ERDA continued it, and DOE is still adding to the great power of nuclear medicine as it develops new isotope-based concepts and tools for radiobiomedical research.

The AEC-ERDA-DOE biological effort was initially aimed at knowledge of the effects of radioactivity, but it was soon found that radioactive isotopes have unique value for understanding biological processes, pointing to additional treatments or cures of illness.

Advances such as PET would almost certainly not exist had DOE and its predecessors not provided the framework. The PET technique has been adapted for other research advances which enhance the progress of the National Institutes of Health. (Appendix E gives an example: recent progress toward understanding (and possibly treatment) of cocaine addiction.)

In recent years NIH has supported roughly twice as much research in nuclear medicine as DOE. The latest available data for NIH show $45 million in 1987. (7) The DOE budget was $33 million in 1991 and, by 1998, had been eroded to $29 million in constant 1991 dollars). (8)

In nuclear medicine, NIH targets understanding of disease as a route to treatments or cures. In this context, NIH has a new Diagnostic Imaging Center, with three of its four parts focused on biochemistry.

A base of improvement can be found in the existing beneficial com-plementarity between the programs of the National Institutes of Health and the Department of Energy in nuclear medicine and isotope-based biomedical research/education. One of the clear conclusions of our study is the value which would be realized by the forming of a joint NIH-DOE program, endorsed at top agency levels, of research and education in the biomedical areas involving isotopes. (7) A step toward such a program was a joint DOE/NIH workshop to discuss their common interest in isotope-based medical and biological research and education (8) and the above-mentioned Diagnostic Imaging Center, headed by a well-respected academic. (40)

Effects of Underfunding on Education and Training

There is an unsustainable ratio between the large numbers of patients who benefit from nuclear medicine (tens of thousands daily in the U.S.) and the currently tiny number of the teachers of teachers in an indispensable part of the base from which these benefits flow. In 1988, Science magazine alone carried 40 adver-tised openings for Ph.D.'s in radiopharmaceutical chemistry. (36) Yet the nationwide number of nuclear and radiochemistry faculty, who prepare radiopharmaceutical chemists for production and research to serve nuclear medicine, were just 12 in 1992, and are still falling! (24)

A 1995 IOM Committee report (1) observed that "Within nuclear medicine the primary areas of need are in radiochemistry (analysis and synthesis), training in the use of instrumentation, the design of new radionuclide generators, optimization of radionuclide production at accelerators, and development of new applications. The committee (noted the important need) to ease the current shortage of nuclear science professionals."

Shortages of isotope experts in medical and biological fields are becoming more acute. (1) Nuclear medical advances depend in turn on innovations in radiobiology and radiochemistry. Needs for experts in these fields have grown, but the numbers being trained have fallen behind that growth. (41)

The number of researchers in nuclear medicine and other isotope-based biomedicine is dwindling, with too few young nuclear medical researchers and too few young biomedical scientists to fill the shoes of retiring investigators. "...(V)irtually all of the advances in the technology, procedures and applications of nuclear chemistry today are the direct results of research supported in whole or in part by the DOE." (6) But DOE's biomedical research-and-education, uncompensated for inflation, suffered a 15% cut in constant-dollar support between 1993 and 1997. (8)

Many centers in the cyclotron-PET and SPECT fields are unable to hire the trained chemists they require (8); there are now very few programs training chemists in the nuclear medicine technologies. Why the lack of interest of university chemistry departments in this sub-discipline? Because of the aforementioned inadequate funding of research/education in nuclear and radiochemistry and other inattention. Correction is now direly needed.

According to acclaimed scientists in PET-based biomedical research, "The important point is that there is presently no formalized, long-term commitment to support postdoctoral training for the chemists required to staff the existing and anticipated clinical and research facilities. Multidisciplinary training cannot replace a rigorous education in the basic principles of chemistry followed by specialization." (5)

DOE's funding of basic research and its accompanying education in radiochemistry has for years been miniscule, and has only in recent years been augmented by funding for environmental cleanup research. (42) There are still far too few young radiochemists. These are key experts in devising more effective radiopharmaceuticals. The damage spreads, since teachers of radiochemistry have another key role: preparing solidly based radiopharmacists, a group in very short supply. This must be corrected.

Another DOE potential which should be solidly re-strengthened is its encouragement of research and education in isotope fields by the supplying of uncommon isotopes. Production of such radioiso-topes has been very limited for years. (1) Further, the Oak Ridge calutron production of stable isotopes, which include many raw materials for producing radioisotopes, has been suspended. (43)

Researchers' choices of isotopes are now confined to readily available ones, usually not those having chemistry and radioacti-vity best suited to the purpose at hand. This diminishes the chances of physicians and patients for better and, overall, less expensive care.

It was recommended to DOE in 1989 that a facility dedicated to production of radionuclides for research be established. (6) A committee of the Institute of Medicine examined the possibility and in 1995 recommended a National Biomedical Tracer Facility for producing radioisotopes for commerce and research, performing biomedical research and educating experts. (1) The idea was shelved after a competition determined that construction would cost ten times the likely annual sales of commercial radioisotopes, and that the DOE share of operating costs might be siphoned from the support of research.

For continued advances in nuclear medicine and other isotope-based research, opportunities for greater choice of isotopes in research and training must be seized. Such opportunities can be brought to reality in existing DOE facilities by providing small funding additions. Other possibilities may exist in cyclotron facilities being phased out of the National Science Foundation's physics program. (30)

NUCLEAR ENGINEERING

Over one-fifth of U.S. electricity is generated by nuclear power plants, which must have a continuing supply of experts to keep them safe and effective. (18) Therefore we must have strong university programs in nuclear engineering (and nuclear physics, nuclear and radiochemistry, and health physics).

Protecting the U.S. against terrorists and rogue nations includes preventing the theft or sale of nuclear weapon materials from such tempting sources as weakened sites in the former Soviet Union. U.S. nuclear physicists and nuclear engineers are depended on for this.

Nuclear engineers are necessary in the team producing isotopes for nuclear medicine, which must have steady, reliable sources of isotopes.

For these and other segments of the national infrastructure, in the 1960's the Atomic Energy Commission recognized the pressing national need for people skilled and knowledgeable about uses of isotopes. AEC provided funds and encouragement for graduate fellows in nuclear engineering, supported their professors' research using universities' research reactors, and contributed to the expenses of reactor fuel.

Because university reactors have broad use in research, teaching and technology beneficial to the economy, their number is a good measure of strength in nuclear engineering education. There were 76 in operation in 1970. Cuts in Federal support in the 1980's brought that number down to 27 in 1987. (10)

The 129 AEC fellowships of 1963 declined to zero in 1970. By 1987 only 39 nuclear engineering degree programs remained. Between 1978 and 1988 there was a 40% decline in nuclear engineering enrollments and a 30% decline in number of universities involved. (9, 32) Enrollments were 2,100 in 1977 and 1,000 in 1995. (18) By the latter year, however, demand had dropped below the number of graduates. (44)

In that situation, as active faculty members were aging and some retired, new faculty were not hired. Also, the fraction of foreign graduate students was increasing: by 1993 it was 30% for the masters' and 40% for the Ph.D. The effect of this decrease in numbers of American students is worsened by the requirement of U.S. citizenship in some federal positions. (32)

During the 1990's DOE funding decreased for research related to power reactors, but research and development increased in other areas of nuclear engineering: environmental remediation, nuclear waste management, space exploration, new means of generating and storing electrical energy, and isotope production and use. (32)

Congress responded to this accumulating damage by mandating, in each of the years 1990-93, that DOE provide $10 million for nuclear engineering research and support of university reactors. This funding met an urgent need to begin re-strengthening such research and improving the aging reactor facilities for the research and its attendant education. Soon afterward, the DOE/utility company matching grant program was initiated, with an annual $800K from each side, for nuclear engineering research, faculty start-up funding, fellowships, scholarships, etc. at 17 campuses. (10) There was a 5-year commitment which ended in 1997, but the matching con-tinues. (45)

But in 1994 the $10 million, which had been added each year by the Congress, was cut to about $4 million. This eliminated the grants for nuclear engineering research and equipment for upgrading uni-versity reactors. This change overlooked the vital role these reactors played in maintaining U.S. leadership in nuclear techno-logy, its safety and its environmental and economic benefits including exports. (10, 11, 33)

There was another very damaging change in 1994. The Laboratory Cooperative education program, which had long and productively provided an annual $5 million for students' unmatched research experience at national laboratories, was devastated in the appropriations for the Office of Energy Research. Brookhaven's Lab Coop effort was terminated, Argonne's was reduced and Oak Ridge maintained only its minority-oriented part. (10, 33) Completing this devastation, in 1998 the Lab Coop program was entirely canceled, despite a Senate effort to provide $10 million for it and for pre-college minority education.

The combination of dramatic decline of these DOE activities and lower demand for graduates caused further losses in nuclear engineering: between 1995 and 1996 doctorate enrollments fell 8%; master's, 15% and bachelor's, 22%. (35, 46)

Dwindling enrollments and numbers of graduating nuclear engineers are not yet leading to shortages, due to continuing (but now leveling) shrinkage of employment opportunities. (44) On the other hand, the dramatic weakening of support of education in nuclear engineering cannot be allowed to continue to the point that future needs cannot be met. Unless timely correction is made soon, this important part of our infrastructure for security, safety, medicine and our technological economy will fade so far that recovery, when importantly needed, will take too long. That calamity will be due not only to the shortage of capable faculty but also to the fact that nuclear engineering education and research require more intricate installations than other fields of engineering. (10, 11)